2006/2007

Forest Genetics Council of BC

Tree Improvement Program Project Report

INSIDE COVER

Forest Genetics Council of BC

Tree Improvement Program Project Report

Coordinated and compiled by:
Beacon Hill Communications Group Inc.

and

Keith Thomas
Tree Improvement Branch
British Columbia Ministry of Forests and Range

Acknowledgements

The Tree Improvement Program is now in its tenth year and has proven to be one of the most enduring and successful partnerships sponsored by the Provincial Government. Through your hard work and dedication this program has been quick to respond to the ever-changing environment and this year has been no exception. Mountain Pine beetle continued to be an issue and for the first time attacks were recorded in our southern interior orchards. We are very appreciative of Jim Corrigan, Robb Bennett, and the Pest Management TAC for being so responsive and providing excellent mitigation strategies that reduced the impacts and protected our orchards.

This was also a year of transition. Roger Painter after dedicating the last ten years of his forest service career to the Tree Improvement Program bid farewell and retired. This program owes a lot to Roger because without his tenacity and perseverance this program would not be what it is today…Thank you Roger. We wish Roger the very best and I am sure we have not seen nor heard the last from him.

Climate change continues to be at the forefront and over the next few years our energies will be focused on providing a comprehensive operational program for improved seed supply in the face of a changing climate. This will not be easy but I have no doubt that all our subprograms will rise to meet this challenge.

The Forest Investment Council continues to recognize the value of investing in tree improvement. One of the key elements to our success is our goal of continuous improvement. Each year a review of at least one of our programs is done to ensure that it aligns with Council's Strategic direction and continues to deliver value for investment. The processes we have in place will ensure a transparent program that delivers on its targets, continues to be well respected, and is used as a standard for others.

This publication provides an excellent review of our efforts and highlights our successes for the forest industry. Sincere thanks to the Project Leaders for submitting their contributions in a timely fashion, and to Diane Douglas, Nick Ukrainetz and Gary Giampa for taking the time to review them. Acknowledgments also to Jim Corrigan, Lorraine Maclauchlan and Chris Walsh for providing the images for the front and back cover of this year's report.

Again, thanks to all those who have worked on this program in the past year and over the past ten years, including the review committees, species committees and various TAC's. You are the reason that this program has a strong technical direction and is so successful. Congratulations to you all for an excellent tenth annual report. I hope you enjoy it. To all the Project Leaders, I wish you continued success for 2007/2008.

Keith Thomas
Tree Improvement Co-ordinator
Forest Genetics Council

Forest Genetics Council Co-chairs

Once again we thank the many industry and government staff who contributed to the provincial gene resource management program for their cooperation and dedication over the past year. Although forestry in BC is changing quickly, there is a consistent and solid base of support for tree improvement, and a well-established planning process in place.

During the 2006/07 fiscal year, substantial progress was made in several important areas:

- The Challenge Dialogue was initiated. The results of this multi-stakeholder discussion will provide important and relevant input into the shaping of Council's future strategic direction and upcoming 5-yr plan review.
- Ongoing Council membership changes were completed allowing long-serving councilors a rest and bringing new energy to gene resource management in B.C. In addition, the FGC, in its effort to ensure diverse representation, asked to have a First Nations representative on Council.
- A seed supply analysis spurred on by the Mountain Pine Beetle (MPB) epidemic was completed. Recommendations were made and the FGC endorsed key orchard expansions to meet future seed supply demands.

The coming year will continue to present challenges for Council. The MPB impacts on forest management and our orchards continue to be of concern. Through continued diligence and strategic planning Council is working to ensure an adequate seed-supply to meet our future reforestation needs and help meet the Province's stewardship goals.

Your program Co-chairs are confident that Council, and associated committees, will continue to rise to meet these challenges in 2007/08.

John Elmslie
Industry Co-chair

Dale Draper
Ministry of Forests and Range
Co-chair

The Forest Genetics Council Co-Chairs invite you to review the programs and projects described in this report and return any questions or comments to:

Tree Improvement Coordinator
Ministry of Forests and Range
Tree Improvement Branch
PO Box 9518 Stn Prov Govt
Victoria, B. C. V8W 9C2

Further Tree Improvement information can be found at our web sites:

Forest Genetics Council	http://www.fgcouncil.bc.ca
Ministry of Forests and Range, Tree Improvement Branch	http://www.for.gov.bc.ca/hti
Ministry of Forests and Range, Research Branch	http://www.for.gov.bc.ca/hre/forgen/index.htm

FOREST SERVICE BRITISH COLUMBIA

FGC

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Tree Improvement in British Columbia

Ministry of Forests and Range Programs Overview

Forest Genetics Council of B.C.

Genetic Resource Conservation and Management
CIFOR Challenge Challenges

Brian Sanders

[redacted]

FIA – Tree Improvement Subprograms

The Forest Investment Account (FIA) Tree Improvement Program is consistent with the provincial strategy for forest genetic resource management developed by the FGC. The TIP goals are to increase the growth rate, wood quality, and pest resistance of seedlings, and to preserve the genetic diversity of tree species across the province. TIP activities are organized into seven subprograms:

- Gene Conservation
- Tree Breeding
- Operational Tree Improvement Program (OTIP)
- Expansion of Orchard Seed Supply (SelectSeed Ltd.)
- Extension and Communication
- Gene Resource Information Management
- Seed Use Management

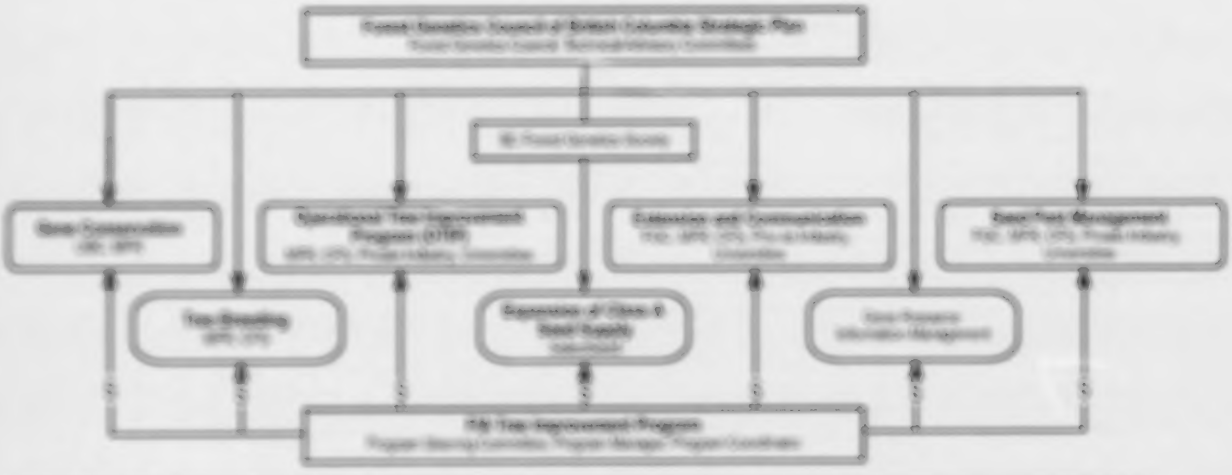


Figure 1. Relationship between FGC Strategic Plan, FIA-TIP, and participants in various forest gene resource management areas.

1.0 Expansion of Orchard Seed Supply Subprogram (SelectSeed Co. Ltd.)

Jack Woods

The Forest Genetics Council of BC (FGC) created SelectSeed Co. Ltd. on April 16, 1999 to expand provincial seed orchard capacity to meet long-term Council objectives for orchard seed use and genetically based plantation gains. SelectSeed is a provincially registered company that is wholly owned by the Forest Genetics Council of BC (FGC) through its registered Society. All SelectSeed orchard investments are through long-term contracts with private-sector companies. SelectSeed also provides program management services for the FGC, including organizing meetings; participating in ongoing policy, structural, and planning issues; preparing business plans and reports; and dealing with legal and accounting matters.

During the fiscal year ending March 31, 2007, SelectSeed orchard developments continued to focus on bringing the orchard trees to the full production stage. SelectSeed orchards carried out propagation to replace mortality by grafting a total of 3,873 ramets. A total of 2,765 ramets were planted across 14 seed orchards, which brought the total number of ramets established to 34,160 (97% of the final planned number) (Table 1). Scion was also collected to assist other operators with orchard expansions.

The young orchards are just entering the production phase, and 2006 produced a good crop of lodgepole pine flowers that received supplemental mass pollination. These will be harvested in the late summer of 2007. Small Douglas-fir and lodgepole pine crops were harvested, but 2006 was an off year for cone production.

SelectSeed provided management services to the FGC, including organizing and planning five meetings, developing a business plan, producing species plans, completing the FGC Annual Report for 2005/06, producing mid-term reports, and dealing with legal and accounting matters related to the BC Forest Genetics Society.

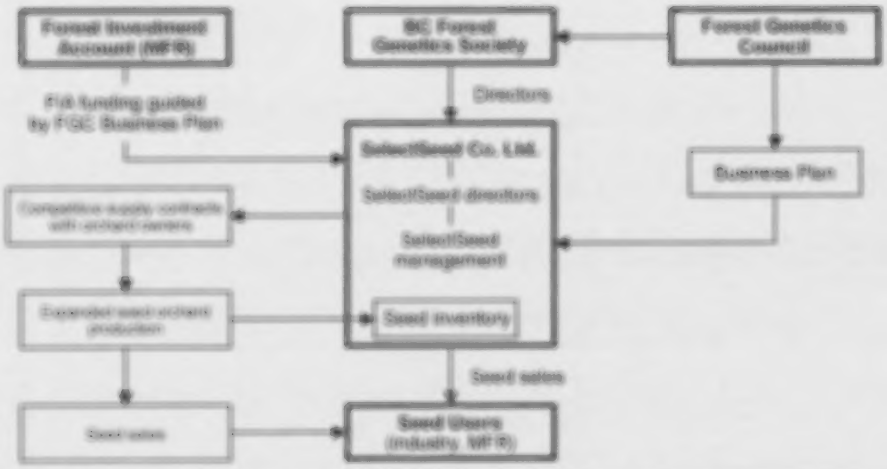


Figure 2. Schematic of organizational relationships among FGC, FIA, SelectSeed and seed users.

Orchard #	Spp.	Seed zone	# ramets grafted	# ramets planted in 2006/07	# ramets currently established	% estab.	Orchard company[1]	Location
321	Fdi	NE low	205	57	2,180	99%	PRT	Armstrong - Grandview
232	Fdi	QL	0	28	815	84%	VSOC	Vernon
233	Fdi	PG	0	17	787	100%	VSOC	Vernon
343	Sx	TO high	0	4	1,051	100%	Tolko	Armstrong - Eaglerock
342	Sx	TO low	0	3	452	99%	Tolko	Armstrong - Eaglerock
337	Pli	NE low	55	18	1000	100%	PRT	Armstrong - Grandview
338	Pli	TO low	448	310	4,761	99%	PRT	Armstrong - Grandview
237	Pli	PG low	1,363	1004	4,615	94%	KRSO	Kettle Valley
236	Pli	PG low	0	118	4,283	95%	VSOC	Vernon
339	Pli	TO high	316	165	3,364	96%	Tolko	Armstrong - Eaglerock
234	Pli	BV low	0	46	2,902	97%	VSOC	Vernon
240	Pli	BV low	349	199	2,964	96%	Sorrento	Sorrento
241	Pli	CP low	360	261	1,951	98%	Sorrento	Sorrento
238	Pli	CP low	777	535	3,019	97%	KRSO	Kettle Valley
Totals			**3,873**	**2,765**	**34,160**	**97%**		

1 PRT – Pacific Regeneration Technologies Ltd.; VSOC – Vernon Seed Orchard Co. Ltd.; KRSO – Kettle River Seed Orchard Company Ltd.; Sorrento – Sorrento Nurseries Ltd.

Table 1. Summary of SelectSeed orchard development status as of March 31, 2007.

2.0 GRIM Project Accomplishments in 2006 and 2007

Leslie McAuley

1. Initiated support for the Genetic Resource Conservation and Management (GRM) "Challenge Dialogue" process to engage the GRM community of practice in: 1) the development of a common GRM Sustainable Forest Management (SFM) vision and 2) active participation in the development of a provincial resource strategy for British Columbia's forest-tree genetic resources. The coming year will see broader stakeholder engagement. The GRM strategy and Action Plan will guide and inform the GRM DSS project (see item 2 below).

2. Initiated a multiple-year project to develop a Genetic Resource Conservation and Management (GRM) decision support system to address new and emerging business requirements, such as spatially enabled seed planning to address Mountain Pine Beetle seed needs, land-based effectiveness evaluation and resource stewardship monitoring, performance reporting (status and trends of GRM practices and genetic resource assets), and development of a climate-based seed transfer system. Developed a draft GRM DSS business architecture, including business mapping (current and anticipated), business requirements (including gaps and opportunities), and a business case (preliminary).

3. Developed linkages between the Seed Planning and Registry (SPAR) system and SeedMap to support clients in seed planning, registration, and seedling request ordering and in meeting information requirements identified in the Chief Forester's Standards for Seed Use. Map layers displayed in SeedMap are produced via a direct link to the Land Resource Data Warehouse, where official Seed Planning Zone source data resides. Completed further enhancements to support the new Chief Forester's Seed Use Standards (effective April, 2005) and the Forest For Tomorrow (FFT) program. A Parent Tree data extract is now available for downloading.

4. Completed the development of the Genetic Diversity indicator for The State of British Columbia's Forests Report. Four questions are posed: 1) How well conserved are the genetic resources of trees? 2) What genetic variation exists in unmanaged and managed forests? 3) What proportion of reforestation uses select seed? 4) Where is select seed planted? Indicator status and trends are based on information extracted from the Reporting Silviculture and Land Status Updates System (RESULTS), Forest Tenure and Administrative Status (FTAS), and the Seed Planning and Registry (SPAR) system. On-line publication is planned for Fall 2007. See http://www.for.gov.bc.ca/hfp/sof/sof.htm.

5. Benchmarking Genetic Diversity in British Columbia from 1970 to 2005 continued through work carried out as an intensive evaluation under the Forest and Range Evaluation program (FREP). The purpose of this evaluation is to benchmark GRM (seed use) practices at the provincial and regional level as we transition from a prescriptive, rules-based policy framework under the previous Forest Practices Code to one that is modeled on a professional reliance framework and results-based outcomes. Indicator status and trends are based on information extracted from the Reporting Silviculture and Land Status Updates system (RESULTS), the Seed Planning and Registry system (SPAR), and spatial and attribute overlays derived from data extracted from the Land Resource Data Warehouse (LRDW). A FREP technical report is currently being developed through external contract.

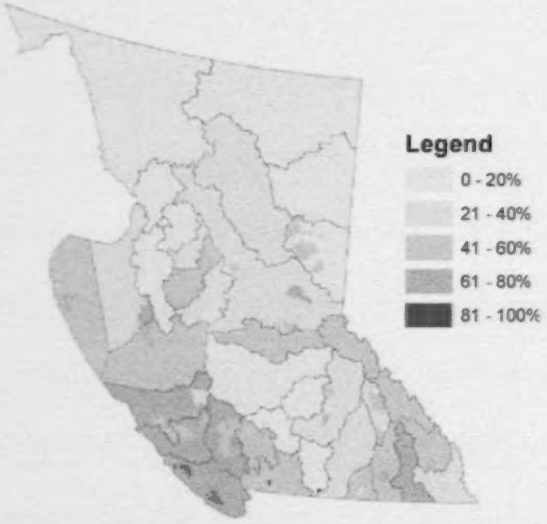


Figure 3. Use of Select Seed, 2002/03. Percentage of Reforested Area Planted with Select Seed, by Management Unit.

3.0 Centre for Forest Conservation Genetics (CFCG)

Sally Aitken

Introduction

In the past year and with much help from our collaborators and others in the forest genetics community in the form of technical assistance, access to data, and seed, and guidance from the Gene Conservation Technical Advisory Committee, the staff and graduate students of the CFGC have managed to make significant progress towards our understanding of the genetic structure and diversity of indigenous tree species and the best ways to safeguard that diversity as a resource for future environmental challenges and future generations. Within the framework of the Genetic Conservation Subprogram of the FGC, we have been able to wrap up several projects and initiate a few more. This report contains summaries of progress to date for our major projects organized into four areas (conservation strategies; cataloguing protection; climate change; and genetics of minor species) and a list of publications from the past year. More detailed information can be found on our website at www.genetics.forestry.ubc.ca/cfgc.

Genetic Conservation Strategies

The CFGC's early research focused on developing conservation strategies. Much of this research has now reached completion with the establishment, acceptance by scientific peers, and publication of minimum thresholds for *in situ* conservation (Hamann et al. 2004, 2006). Two PhD projects completed within the CFGC in recent years focused on different aspects of gene conservation strategies.

Washington Gapare investigated spatial genetic structure within stands and distribution of rare and common alleles at varying spatial scales. He found that sampling strategy does not make much difference to capturing genetic diversity in central populations, but it can have profound effects in peripheral populations (Gapare et al. in press).

Makiko Mimura examined both mating systems and tradeoffs between local adaptation and gene flow in central, peripheral, and disjunct populations to better understand the value of marginal populations for conservation. She found that individual tree seed collections are likely to contain much greater levels of diversity in central than in marginal populations, in part because many fewer male parents contribute pollen to each seed parent in marginal populations and because these marginal populations also experience substantially higher levels of inbreeding (Figure 4; Mimura and Aitken 2007a, 2007b). This might lead some to question the value of marginal populations for conservation. However, she also found that isolated, marginal populations are likely to be adapted to more extreme conditions than those found in the continuous portion of the species range (Mimura and Aitken, manuscript under revision). These results have substantial implications for *ex situ* conservation collections, and they emphasize the need to identify and conserve isolated populations at a species margin.

Cataloguing Protection Levels for BC Tree Species

Since the CFGC's involvement in cataloguing *in situ* conservation started in 2000, a large volume of work has been produced on the *in situ* conservation status of BC tree species (Hamann et al. 2004, 2006). Although many of the results have been published, we have not yet completed an overall, detailed synthesis with specific conservation recommendations. Scientist Christine Chourmouzis is currently preparing a technical compilation and synthesis of this information designed to reach a wider audience and catalyze operational gene conservation activities.

The report is divided into two chapters that deal separately with 1) *in situ, ex situ,* and *inter situ* conservation of commercially important species by SPU; and 2) all indigenous species by BEC zone. Current species range distributions, protection levels across BC, and the potential for range expansion with climate warming are all considered when identifying gaps in protection. The first draft for the chapter on *in situ* conservation of all indigenous species was nearly completed in this fiscal year. Ms. Chourmouzis has started compiling the data for *inter situ* genetic resources (materials under test in the MFR Research Branch's breeding programs) and *ex situ* resources (seed in long-term storage, mostly at the Ministry of Forests and Range Tree Seed Centre) for commercially important species. During the 2007-08 fiscal year, the GCTAC will develop a Forest Genetics Council Genetic Conservation Plan that will provide an operational approach to filling conservation and information gaps identified in this report.

Climate Change

ClimateBC: Our ClimateBC model continues to be used widely in forestry research in BC and the number of non-forestry related applications is growing rapidly. CFGC Assistant Director Tongli Wang is upgrading it continually. Version 3.1 beta, including historical (1901 – 2002) monthly climate data and 1971-2000 normal data, has been developed and is now ready for download from the CFGC website. ClimateBC v3.2, which will use finer (change from 1° to 0.5°) annual anomaly input data, is in development. The web version of ClimateBC v2.3 has been upgraded to version 3.1.

Response of lodgepole pine populations to future climates: This work used growth response functions to determine the performance of each population in the Illingworth provenance trial along climatic gradients (Wang et al. 2006). Results of this study suggest 1) the importance of using reliable climate models in genecology to avoid misleading conclusions and using anchor points and multivariate functions to improve the growth response functions; 2) that populations from the south are not necessarily the best choice for future climates; 3) the identity of populations adapted to a broad range of climatic conditions, particularly from NE low and PG low; and 4) that the potential for using optimized seed source selection to mitigate climate change is substantial.

Graduate student Sierra Curtis-McLane is examining annual radial growth in lodgepole pine relative to changing climate patterns in British Columbia as part of her PhD research. She collected tree cores spanning 25-30 growth rings from nine provenances on 15 sites of the Illingworth provenance trial and is analyzing them to assess annual genotype-by-environment interactions across a spectrum of climatic conditions. She measured the tree rings using standard dendrochronological techniques and will use the measurements to analyze inter-annual variation in provenance growth in relation to weather records. She will compare the results to these provenances' predicted responses to changes in climate.

Predicting future distributions of ecosystems and seed planning units: Andreas Hamann and Tongli Wang used the ClimateBC model in their landmark 2006 publication in the journal Ecology that predicted the future distribution of climates currently associated with BEC zones and tree species in BC (Hamann and Wang 2006). As a continuation of this work and because small spatial units do not translate well into operational practices, Tongli Wang has developed a maximum probability approach to predicting the future distribution of BEC zones and SPUs without extensive fragmenting across BC landscapes. We hope that these methods will be quite useful in the revision of seed transfer guidelines in anticipation of climate change.

Incremental FIA Climate Change Project:

Short-term testing of provenances and genotypes to predict response to climate change and adapt seed transfer policy: Because relatively few species have comprehensive provenance trials spanning a sufficient range of climates to derive provenance response curves, we are attempting to derive such curves based on seedling growth and phenology in controlled growth-chamber environments. Our current experiment builds upon research completed in 2004-2005, which investigated the response functions of lodgepole pine to temperature and CO_2. The previous study found that height and volume growth of seedlings in controlled environments peaked at a simulated mean annual temperature (MAT) of 9°C or higher, whereas this peak was estimated to occur somewhere between 3 and 6°C in the field (Wang et al. 2006). The most important difference, we believe, was that our climate regimes in the growth chambers were built to simulate monthly averages of daily average temperature and daily temperature range rather than daily variations as in real weather and did not include any application of drought.

The new experiment includes more realistic climate regimes based on climatic means for locations with MAT 4°C, MAT 7°, MAT 10°, and MAT 10° + 2 x ambient CO_2, with daily variations added around weekly and monthly temperature averages. Each temperature regime includes both well-watered and drought treatments. The new experiment contains approximately 20 seedlots each of interior spruce and lodgepole pine, including both natural stands and improved seed orchard lots from across a broad geographic range. Most of the interior spruce seedlots are also part of a recently established, large field trial (the Sx genecology trial EP 670.71.12), and the wild-stand lodgepole pine seedlots are also represented in the Illingworth trial. This will allow us to compare growth-chamber data with field-growth performance later on. Seedlings are planted in boxes that allow for extensive root competition; this makes drought treatments more realistic. Plant height is being measured bi-weekly, and the growing season lasts 26 weeks. The experiment will be replicated twice, once now and again in winter, 2007-08.

Genetics and Conservation of Minor Species

Whitebark pine (*Pinus albicaulis*): Andy Bower completed his PhD on whitebark pine in the spring of 2006, and we continue to publish the results of his thesis to help guide restoration and conservation efforts (Bower and Aitken 2006, 2007). He is revising the following manuscripts for publication: 1) the results of the common garden study and tentative recommendations for seed transfer in whitebark pine; and 2) genetic changes of cohorts with age and blister rust infection. Finally, he has completed a draft manuscript on seed stratification treatments, seed storage, and germination. We have also participated in the planning of a workshop on whitebark pine to be held in Whistler in August, 2007, at which Bower will present some of these results. A new study on whitebark pine by PhD student Sierra Curtis-McLane is in the planning stages. It concerns field testing the bioclimatic envelope predictions of current and future distributions from the models of Hamann and Wang (2006) and evaluating strategies for facilitated migration.

Pacific dogwood (*Cornus nuttallii*): Most of our research to date has focused on conifers, and little is known about the genetic structure and diversity of many of our broadleaves. We have projects underway with Pacific dogwood and Garry oak to try to fill some of this gap and to determine if these species show similar patterns of genetic diversity and genecology to those of the widespread conifers that have previously been studied. In 2006, MSc student Karolyn Keir collected fresh foliage from 20 populations and seed from 11 populations of Pacific dogwood encompassing the entire species range (Figure 4). Currently, this leaf material is being genotyped with both nuclear DNA microsatellite and chloroplast markers to obtain estimates of population genetic diversity, structure, and history. Seeds were planted following an acid scarification and cold stratification in January 2007 for a common garden experiment.

Garry oak (*Quercus garryana*): The extent of Garry oak in BC and beyond has diminished greatly over the past century due to agriculture, urbanization, and fire exclusion. There is considerable interest in restoration plantings of Garry oak, but there have been no genecological studies to guide seed transfer for this species, and the ability of this species to adapt to climate change is unknown. In late summer and early fall of 2006, MSc student Colin Huebert conducted a range-wide seed collection, extending from central California to central Vancouver Island (Figure 5). In total, Huebert collected 3,500 acorns from 15 different populations. Average acorn weight was calculated for each family. Acorns were subsequently transported to the UBC research greenhouse where they had a high germination rate. In the autumn of 2007, seedlings will be transplanted from the greenhouse to the outdoor raised beds at UBC, where they will remain until the end of the experiment. A second field common garden may be established on Vancouver Island if a suitable site can be located. The results will be used to develop seed transfer recommendations and predictions of the ability of Garry oak to adapt to climate change.

CFGC Publications in 2006-07

Bower, A.D. and S.N. Aitken. 2006. Geographic and seasonal variation in cold hardiness of whitebark pine. Can. J. For. Res. 36: 1842-1850.

Bower, A.D. and S.N. Aitken. 2007. Mating system and inbreeding depression in whitebark pine (*Pinus albicaulis Engelm.*). Tree Genetics & Genomes. In press; published online at http://dx.doi.org/10.1007/s11295-007-0082-4

Gapare, W.J., A.D. Yanchuk and S.N. Aitken. 2007. Optimal sampling strategies for capture of genetic diversity differ between core and peripheral populations of *Picea sitchensis* (Bong.) Carr. Conservation Genetics. In press.

Hamann, A., and T. Wang. 2006. Potential effects of climate change on ecosystem and tree species distribution in British Columbia. Ecology. 87:2773–2786.

Mimura, M. and S.N. Aitken. 2007a. Increased selfing and decreased effective pollen donor number in peripheral relative to central populations in *Picea sitchensis* (Pinaceae). Am. J. of Botany. 94: 991-998.

Mimura, M. and S.N. Aitken. 2007b. Adaptive gradients and Isolation by distance with postglacial migration in *Picea sitchensis*. Heredity. 99: 224-232.

Wang, T., A. Hamann, A. Yanchuk, G. A. O'Neill, and S. N. Aitken. 2006. Use of response functions in selecting lodgepole pine populations for future climate. Global Change Biology. 12:2404–2416.

Wang, T., Hamann, A., Spittlehouse, D.L., and Aitken, S.N. 2006. Development of scale-free climate data for western Canada for use in resource management. Intl. J. Climatology. 26(3): 383-397.

Wang, T. 2006. ClimateBC: A Computer Program to Generate High resolution Climate Data for British Columbia. TICtalk. 7, 17-19.

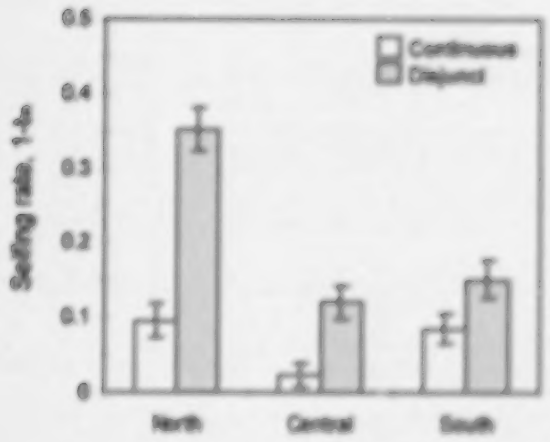


Figure 4. Levels of self-pollination (1=entirely selfing, 0=entirely outcrossing, calculated as 1-tm where tm is the multilocus outcrossing rate) in northern peripheral, central, and southern peripheral continuous and disjunct populations of Sitka spruce (from Mimura and Aitken 2007b). Disjunct (isolated) peripheral populations are likely to have higher inbreeding and lower levels of genetic diversity than central and continuous populations, but are also likely to contain phenotypes adapted to climatic extremes at species margins.

Figure 5. Locations of Pacific dogwood (left) and Garry oak (right) collections in 2006. For Pacific dogwood, triangles indicate locations of populations where foliage was collected for genetic marker analysis, and circles indicate populations sampled for seed. For Garry oak, acorns were sampled at all sites.

4.0 Tree Breeding

4.1 Coastal Douglas-fir Breeding Program

Michael Stoehr, Keith Bird, Lisa Hayton

Low-elevation coastal Douglas-fir (orchard 01)

Coastal Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) remained the highest valued species in BC based on product value (SPU 1). Consequently, seed needs have risen over the past years to over 10.5 million seedlings planted per year. Breeding and testing for a third generation seed orchard continued. In the spring of 2006, we planted the third phase of subline (one of a total of four) on four sites to obtain GCA estimates and on two sites for full-sib forward selections. Forward selections (based on an index of family and within-family performance) were made in full-sib family blocks of phase 1 tests (planted in 1999). From each subline, we grafted scions from three full-sib seedlings from three families each to speed graft development before making final selection decisions after wood density evaluations (in 2007). We are also currently looking at the use of optimum selection techniques to better balance gain and genetic diversity (relatedness) in the breeding and production (orchard) populations. We measured realized gains in the late fall of 2006. Genetically improved stock was outperforming wild-stand controls on all four sites.

Coastal-Interior Transition Zone (sub-maritime) zone (SPU 18)

In the interior-coast transition (sub-maritime) zone, we assessed three progeny tests planted in 2005 for survival and rugged shoots. We will use this set of tests to estimate breeding values for parents in orchard 181 (backward selections), but we will supplement it with forward selections from open-pollinated genecology tests located in the sub-maritime zone (railroad site on the Hadley Road). We have already selected 20 genotypes from this site based on BLP estimates of individual trees. In co-operation with Barbara Hawkins (UVic), we are initiating a seedling drought-resistance study with a random set of 20 families from the 19 progeny test.

High-elevation (300–1,200 m) coastal Douglas-fir (SPU 19)

We measured two open-pollinated progeny (age 11) test sites (at Sutton Creek and Mt. Cain on Vancouver Island) for estimates of breeding value and for a selection of parents for CANFOR's high-elevation seed orchard (1146). We made backward selections based on BLP estimates, damage sustained on the lumber site (Mt. Cain), and growth stability across the two. Selected parent trees will be re-grafted from clones in CANFOR's orchard at Sechelt and re-established in Saanichton at WFP's orchard complex. Expected gains for this orchardate around 15 percent for volume at rotation (80 yrs). Because of genotype-by-environment interaction (GxE), we applied an independent culling strategy in which we evaluated growth potential for Sutton Creek and damage sustained at the Mt. Cain site. This eliminated some of the faster-growing parents from inclusion in the orchard because their progeny was heavily damaged at Mt. Cain.

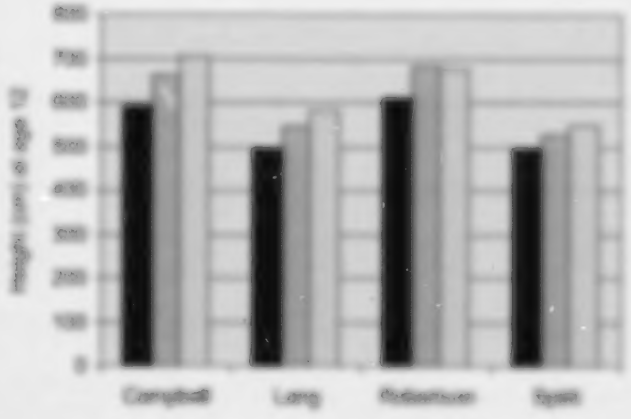
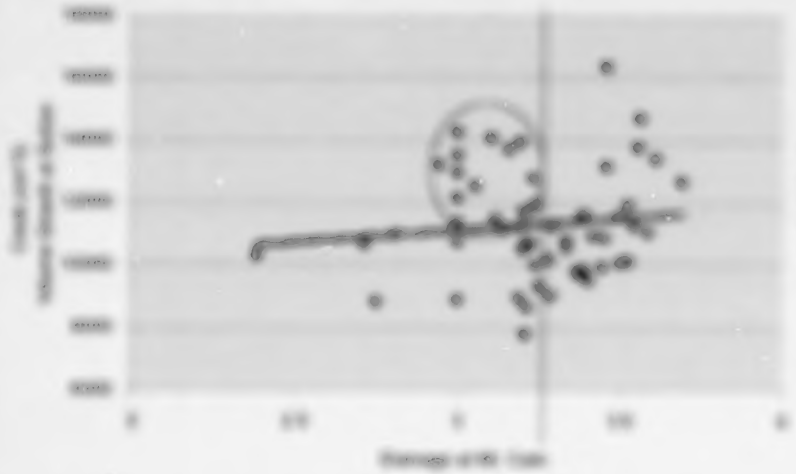


Figure 6. Heights of coastal Douglas-fir at age 11 for seedlings in three genetic classes across four sites.



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4.2 Sitka Spruce Breeding Program

John King, Dave Rowland

Breeding population progress

This year we are entering the third and last series of the F1 breeding programs — second generation. We designated parents for three phenotypic extremes in the second and third series: Growth, Form, or Big Quadrocone. We also made some susceptible patterns. This year we also planted the last of the OP collections from around the Big Quadrocone area.

Selection and breeding work continues, but our focus in the past year is on values and breed for specific traits. The selections will still be field assessed for resistance after natural regeneration. but we are undertaking a more detailed microscopic evaluation in order to classify parents according to genetic mechanisms. This is particularly valuable for "resistance" types of mechanisms such as reduced cells or resistance resin cells, and we are working on several tissue techniques to look at some of the "unbuffer" mechanisms particularly resistance resin cell production.

Ongoing trial assessments for second cycle have continued, and there have included some of the hazard assessment trials. There were a series of trials established in 1972 continues over a series of ecological zone and potential second hazard areas. The main objective is to aid in determining deployment guidelines. This exercise will be carried out with Dave Fergusson, the Crown Regional Entomologist, and we hope to provide regional guidelines for spruce over the next year.

Major articles published over the last five years include:

King J.N. and Miller R.G. 1994. Breeding for resistance to white weevil in Sitka spruce in British Columbia, Canada. In: Cannon M.G., Mullick D. eds. Resistance Forest Biotechnology for the 21st Century. 1994 Forest Research, New Zealand.

King J.N., Miller R.G., and Cartwright C. 1994. Genetic resistance of Sitka spruce (Picea sitchensis) populations to the white pine weevil (Pissodes strobi). Silvae Genetica 43 (2-3): 69-78.

Miller R.G., van Miller G., Jaquish B., and King J.N. 1994. Weevil resistance of progeny derived from genetically resistant and susceptible resistive spruce parents. Tree Genet. and Genom. 3(4):493-511.

Miller Rose G., Cartwright C., Yanchuk A., Vanderbilt, Mr. Alvarez Uribe, Miller R., King J.N., Andersson C., and Rose S.L., 1999. Weevil resistance of coastal Sitka spruce: variation in Sitka spruce from stable resistance to susceptibility as revealed by the white pine weevil. Plant Physiology 1(4): 1049-1063.

Other Components — Q.C. and Spruce Program

The Queen Charlotte Island (QCI) program allows us to assess Sitka spruce from those areas for growth and yield and the Stock Orchard program. BC1 (1) and its replacements. One major difficulty has been in getting "free to grow" conditions, as this can test the three second cycles. A fourth has been established, and a good deal of site maintenance effort is a constant pressure.

The coastline program is designed mainly to test yield, susceptibility to [illegible] environmentally favourable sites with genetics from both these and inland. This year we did an assessment of [illegible] damage.

4.3 Interior Hemlock Tree Genetics Program

Charles Cartwright

Introduction

The objective of the hemlock tree genetics program changed substantially this year. Because of reduced planting in [illegible] of interior, an extended regeneration and harvesting [illegible] of interior hemlock [illegible] stands, assessments of advanced generation trials were postponed to more [illegible] of first generation trials. Maintenance and [illegible] of hemlock tree trials and breeding activities were reduced [illegible] to emphasis on planting trials "in stock" through [illegible] and collection of [illegible].

A [illegible] program was proposed in 1992 to [illegible] establishing the second [illegible] which have not [illegible] program. The [illegible] provide [illegible] and thus wide range [illegible] [illegible] and planting [illegible] [illegible] of [illegible] in [illegible] [illegible].

4.4 True Fir Forest Genetics

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4.5 Western Redcedar Breeding Program

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4.6 Yellow-cedar Breeding Program

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mountain-forecasted superior growth. On average, the Submaritime provenance was 14 percent taller than source-from the Interior Cedar Handbook zone. Mean tree volume of the Skykomish provenance was 52 percent larger than Salmon Arm, the largest interior provenance. Sources from the south-western US survived poorly and grew slowly (Figure 10), while trees from the two Mexican sources have all died. Forward selections were made with the best Submaritime provenances (Figure 11). Pollen was collected from these selections to include these trees in the second-generation Interior Douglas-fir crossing program (Figure 12).

Figure 9. Ameliaria fruiting bodies on artificially inoculated fresh Douglas-fir test seedling. Fungus was harvested in the rooting medium through the inoculated paper band. Black seen in background.

Figure 10. Thirty-year-old Browns provenance showing extreme maladaptation to the Trinity Valley site.

Figure 11. Forward selections in the Cherry provenance in the Trinity Valley range-wide provenance test.

Figure 12. Rubbing pollen from forward selected trees in the Trinity Valley range-wide provenance test. Pollen will be used in Interior Douglas-fir second-generation crossing.

4.10 Interior Spruce Tree Breeding Program

Barry Jaquish, Val Ashley, Gisele Phillips and Bonnie Hoogs

The Interior spruce tree-breeding program in British Columbia is structured in two phases. Phase I began in the mid-1960s and focussed on three geographic regions: Prince George, Bulkley Valley, and the East Kootenay. Phase II began in the mid-1970s and focussed on other geographic regions where Interior spruce is commercially and ecologically important. The program has progressed to the point where much of the current planting stock (more than 80 million seedlings per year) comes from rogued first-generation seed orchards, and full-sib second-generation progeny tests are in place for three seed planning units. In 2006, 65 trees in the 10-year-old Series I Prince George Selection Unit second-generation progeny tests (Figure 13) were selected, grafted, and established in holding beds where they will be held for one to two years and then moved into seed orchards.

In the mid-1990s Interior seed planning zone reviews, the Prince George Interior spruce SPU was realigned to include six small seed planning units from the Phase II program and the Prince George Selection Unit from the Phase I program. This realignment resulted in a composite breeding population of 1,140 tested parent trees for the new Prince George SPU. The second-generation crossing plan for this new zone consisted of crossing the top 144 parents in a six-tree incomplete partial diallel crossing plan where each parent was crossed with four other parents. This plan resulted in 24 partial diallel units and a maximum of 288 crosses. Crossing was completed over four breeding seasons, and four progeny trees were planted in spring 2006. These trees were established in an incomplete block Alpha design with ten replications per site, 13 blocks per replication, and 20 seedlots per block. Experimental units consisted of three-tree row plots with trees planted at 2 x 2 m spacing (Figure 14).

In spring 2006, four realized gain trees were established in the Prince George SPU. These trees will compare the growth performance on an area basis of elite families, seed orchard seedlots, and a wild stand seedlot comprised of a composite of ten wild stand seedlots.

Site maintenance and measurements were conducted on various research sites, including the 10-year-old East Kootenay second-generation progeny tests, the spruce seed orchard effects field tests near Prince George, 12 spruce climate change study sites, and the Chilliwack Provenance.

Controlled crossing to produce full-sib families for second-generation selection is ongoing in the Nelson and Thompson Okanagan SPUs (breeding for TO SPU conducted by Tolko Industries at the Eagle Rock seed orchard).

Figure 13. Ten-year-old Series I Interior spruce second-generation progeny test near Prince George, BC.

Figure 14. One-year-old Interior spruce Series II progeny test at Prince George Tree Improvement Station.

4.11 Western Larch Tree Breeding Program

Barry Jaquish, Val Ashley, Gisele Phillips and Bonnie Hooge

Commercial planting of western larch continues to increase in British Columbia with over 6.6 million seedlings planted in 2006. Sixty-eight percent (4.5 million) of these seedlings originated from seed orchards located in Vernon. Sixty-five second-generation crosses were completed, and 103 pollen lots were collected and stored for future crossing. Second-generation crossing in the East Kootenay and Nelson SPUs is over 70 percent complete, and we anticipate completion of the crossing program within three years. In spring 2006, grafting was completed for the establishment of a new high-elevation seed orchard for high-elevation sites in the Nelson SPU. Realized gain genetic tests were established in the East Kootenay and Nelson Low SPU in 2005 and 2006, respectively.

Maintenance of the subalpine larch (*Larix lyallii*) *ex-situ* gene conservation archive in Vernon is on-going (Figures 15 and 16).

Analyses of the 10-year Series II Nelson SPU progeny tests were completed. Family mean ten-year height ranged from 316 to 564 cm, while breeding values for rotation-age mean tree volume estimated by BLP ranged from –48 to 40.5 percent

Figure 15. Subapline larch growing at Pedley Pass (elevation 2,300 m) near Invermere, BC.

Figure 16. Subalpine larch *ex-situ* gene conservation/breeding archive at Kalamalka Forestry Centre, Vernon, BC.

4.12 Lodgepole, White and Ponderosa Pines and Interior Broadleaved Species

Michael Carlson, John Murphy and Vicky Berger

Winter scion collections were made for Pli; 1) a central interior western gall rust resistance seed orchard, 2) an NE low replacement seed orchard for the existing 307 orchard, and 3) for a new NE high seed orchard. Another scion collection was made for a new Py seed orchard drawing upon selection work in our 14 yr-old ponderosa pine provenance trial at the Skimikin seed orchards site.

Scion from 35 selected/tested paper birch trees (*Betula papyrifera*) were collected and grafted at the Kalamalka Forestry Center with the grafts subsequently divided between the Vernon and Skimikin sites. Two small birch seed orchards will produce seed for the southern interior and the climatically milder portions of the central interior, transfer limits to be determined. Additionally, 21 silver birch (*B. pendula*) trees were selected from three separate long-term trial series at the Skimikin site. These will be scion collected and grafted in 2008 to replace our 16 yr-old seed production stand at Skimikin which is under attack from the Bronze birch borer. The Bronze birch borer is thought to be at least partially responsible for the relatively wide spread paper birch mortality occurring now in the southern interior of BC. Silver birch has been grown and seedling samples distributed to B.C. and Alberta private lands cooperators for several years with excellent results. We foresee a demand for silver birch seed/planting stock in the future.

12 prospective trial sites for the 2007/2008 FMOMSAT series were located and ready for layout in 2008 (see: Greg O'Neill's et. al. "Assisted Migration of Multiple Species Adaptation Trial" writeup).

4.13 Assisted Migration Adaptation Trial

Greg O'Neill

Approximately 50 percent of all seed used in the province originates from seed orchards. By 2013, this amount is expected to be 75 percent. The majority of the progeny tests used to evaluate orchard seed were established when climate change was not perceived as a significant issue and transfers of seed over large geographic distances were not envisaged. Consequently, the vast majority of orchard parent trees have been tested only within a narrow climatic range and only within the breeding zone from which they originated. Without better understanding of their productivity and health responses across a wider climatic and latitudinal range, it is difficult to predict which orchard seedlots will be most productive under future climate projections, particularly when long-distance migration of seed becomes more frequent.

To ensure that the gains achieved through four decades of tree breeding in BC will be realized in a future seed-deployment system, an extensive set of Class A seedlot tests is required across a diverse array of climatic and latitudinal environments. By relating test-site climate to the productivity of each seedlot, those species and seedlots that will maximize the productivity of BC's forests in future climates can be identified (Figure 17). Furthermore, by planting the seedlots in large block plots, and including wild-stand (Class B) seedlot controls, the tests will enable realized gains of the orchard seedlots to be measured.

An experimental design for this project has been extensively reviewed by staff inside and outside the MFR, with input from a growth and yield consultant. To ensure that the test sites sample the breadth of climates within BC, staff from the MFR Research Branch have identified 48 climatic regions in the province, with the aim of establishing a test site within each region. During summer 2007, staff will begin examining candidate test sites and will also confirm test seedlots to be tested. Sowing will begin in April 2008.

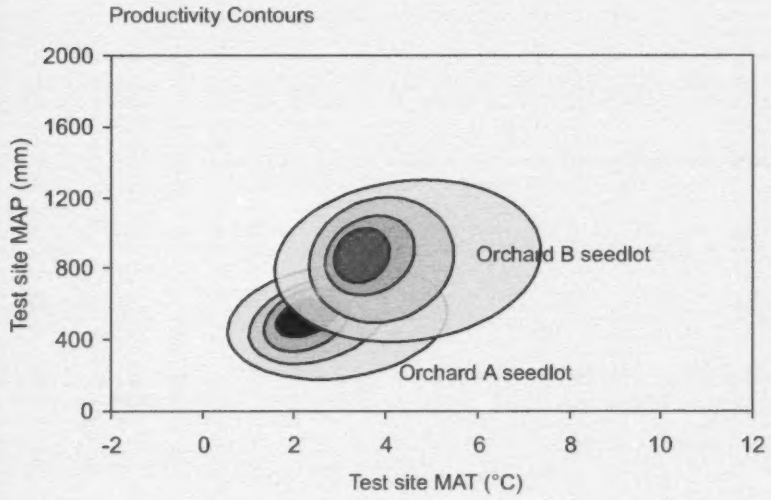

Figure 17. Example of possible genetic worth responses of seedlots from two seed orchards based on two climate variables. Knowledge of such responses could alter seedlot selection decisions and improve adaptation and productivity of plantations. In addition, knowledge of responses would greatly improve the ability to make informed decisions regarding assisted migration of species and seedlots.

5.0 Operational Tree Improvement – the Tenth Year in Review

Keith Thomas

With the end of our Tenth Year, Mountain Pine Beetle continues to attack our forests and our ability to regenerate them will largely depend on our capacity to have quality seed available for our reforestation efforts. After careful planning and analysis the Forest Genetics Council (FGC) approved a plan to expand our seed orchards to meet this expected increase in seed demand. This plan will take a number of years to implement but by the time these seed needs arise our new orchards will be in production.

The Tree Improvement Program has the ability to meet future seed demands due to key investments in breeding, testing, seed pest management, OTIP, and SelectSeed. Over the years the Operational Tree Improvement Sub-program (OTIP) has provided the focus for investing in our orchards for the purposes of increasing genetic gain as well as seed yields. Seed requests in 2006-07 equated to 285 Million seedlings, 49% of which were select with an average Genetic Worth of 12%. This sub-program continues to invest in existing orchards enabling them to realize their potential. This, coupled with the development of replacement stock from the breeding programs, ensures that the genetic worth of orchards continues to climb. In addition, our program utilises a system of performance management to monitor progress and set reasonable targets for project success. Orchardists and researchers have responded to these approaches, and in many instances have surpassed targets.

Although 2006-07 was a moderate year for most species crops, considerable work continues with stock replacement and studies on seed supply. There are still numerous insect-related issues that reduce seed yields. However our strategic decision to develop the Seed Pest Management Technical Advisory Committee and its associated sub-program along with stronger mandate for research and the work being done through Professor von Aderkas at the University of Victoria has placed us in an enviable position to respond to these issues. This is another example of how leadership in the overall program allows us to effectively meet new challenges and focuses our efforts on the issues at hand, irrespective of fixed funding levels. As a result, the Forest Investment Account continues to show strong support for our program and funding levels are expected to remain relatively constant for the foreseeable future.

In 2006-07, the two OTIP technical review committees reviewed a total of 84 proposals. The total amount of proposals received was approximately $872,000, of which the Coastal and Interior technical committees recommended approving $720,964 (Table 2). The breakdown of investment by region for all of OTIP is as follows:

Region	Projects Approved	Funding Approved
Interior projects	52	$471,625
Coastal projects	28	$249,338
Overall Total	**80**	**$720,964**

Table 2. Number of projects and funding by region.

Numerous species committees support the FGC by reviewing and developing annual projects and priorities. Both the Tree Breeding and the Operational Tree Improvement Program receive their direction from these reviews. Similarly the Extension and Gene Conservation TACs have developed their own priority review procedures. Tree Breeding is a Ministry of Forests and Range responsibility and is not part of the OTIP "Call for Proposals" process. Priorities for the Tree Breeding sub-program are still developed through the species sub-committees, but decisions on projects to be undertaken are reached through co-ordination with the Tree Improvement and Research Branches of the Ministry of Forests and Range and the FGC Program Manager. Considerable investment is needed in this sub-program, and it will continue to receive strong levels of support to ensure the development of new production stock for future orchards. New orchards focus on producing seed for Seed Planning zones where production capacity is low and/or where priorities for genetic quality seed are high. There will be a continued need for this as climate change forces us to re-think current seed planning zones. New orchards also help produce stock to replace older less advanced stock in existing orchards. Work in Tree Breeding has already provided much of the genetic material to establish a number of new orchards and to enhance existing ones. In addition, the development of a long-term investment

program through SelectSeed Ltd. will eventually produce over 35,000 grafts to establish new orchards.

Technical support within the OTIP sub-program is an integral part of tree improvement and provides an excellent venue for operational problem-solving. The lodgepole pine seed-set issue is an excellent example of a focussed investigation to solve a serious problem that affects tree improvement. In addition, this program area will also work on orchard issues related to mountain pine beetle. Table 3 lists the project breakdown by areas of investment for 2006-07.

Area of Investment	No. Projects
Tree Breeding	28
Gene Conservation	8
Operational Production	61
Technical Support	14
Seed Pest Management	5
Extension and Communication	6
Seed Planning and Information Tools	4

Table 3. Number of project/area of investment

The tree improvement industry represents a broad spectrum of partners that includes forest companies, the provincial government, the Canadian Forest Service, universities, private bio-technical companies, and individuals. In 2006-07 the Tree Improvement Program involved 37 separate contributors from all parts of our industry. The FGC continues to provide sound leadership and management through its technical committees and continuous improvement of its strategic direction, goals, and programs.

5.1 Orchard Projects

5.1.1 Saanich Forestry Centre (WFP)

Annette van Niejenhuis

The Saanich Forestry Centre, wholly owned and operated by Western Forest Products Inc., manages production tree seed orchards for low-elevation Douglas-fir, low-elevation western redcedar, low- and high-elevation western hemlock, and low-elevation Sitka spruce seed planning units, together with hedge orchards for the yellow cypress seed planning unit, all in the Maritime Zone. As a co-operator in the Forest Genetics Council programs aimed at delivering quality seed in quantity to the coastal forest regeneration programs, WFP employs incremental management techniques using funds from OTIP.

Coastal Douglas-fir Crop and Orchard Enhancement

Orchard upgrading included removing 22 ramets and planting 80 ramets. The rogued ramets represented clones with a consistent history of cone abortion. Ramet replacement has raised the breeding value of this orchard to 15.5.

The 2006 cone crop was of low volume, coming in at 9 hl with a genetic worth of 11. High levels of insect damage resulted in seed recoveries far below average. Just over 1 kg of seed was registered on SPAR from this crop.

Western Redcedar Orchard and Crop Enhancement

Supplemental mass pollination in the previous year resulted in a western redcedar crop of 4.6 hl of cones. Seed recoveries were near average, resulting in 2 kg of seed from this crop with a genetic worth of 6.

Induction using GA_4 applications in the second quarter resulted in good flower set for the 2007 crop. Controlled pollinations of 1,500 bags are underway using fresh pollen. Additionally, 54 controlled pollinations are testing the viability of stored pollen from the 2006 crop year as compared to fresh pollen. Seed set as determined by germination tests will be used to measure the success of western redcedar pollen storage at Saanich Forestry Centre. Monitoring for western redcedar cone midge indicates low incidence in the 2007 crop to date.

Low-elevation Western Hemlock Crop Enhancement

Supplemental mass pollination was applied to the 2006 western hemlock crop, focussing on clones with a propensity to self. A small crop of 2.8 hl of cones was harvested. Extraction of the crop netted 2.7 kg of seed, reflecting good seed set. The genetic worth of this seedlot, as registered on SPAR, is 16.

To determine if the pollen cloud in this orchard of mid-size trees is adequate or whether supplemental mass pollination for seed set is still required, two replicates of 10 clones were selected for a comparison of seed set. Each selected ramet was a "crop tree" showing good female flower abundance. One of the two replicates of each clone received supplemental mass pollination, and the second did not. At harvest, a sample of 10 cones from each ramet was evaluated for seed set. No significant differences in the number of filled seed per cone were detected between those cones that received supplemental mass pollination and those that did not, with an average of 13.8 and 11.3 filled seeds per cone respectively.

High-elevation Western Hemlock Orchard and Future Crop Enhancement

Ramet replacement continued with the planting of 185 ramets. Extensive site preparation was undertaken to improve the survival of hemlock. The orchard now has a breeding value of 11 and includes 28 parents.

All ramets with a crop were treated with supplemental mass pollination in the first quarter. Pollen was harvested, extracted, and stored for application to future crops. A small crop of 0.3 hl of cones was harvested from the high-elevation hemlock orchard. Only a portion of the crop was

Figure 18. A controlled pollination crop is managed in the western redcedar seed orchard at Saanich Forestry Centre to address the effects of selfing and to assist in midge control.

Figure 19. The 2007 low elevation western hemlock crop at the Saanich Forestry Centre demonstrated good seed set, delivering seed with a genetic worth of 16.

registered to maintain the genetic worth of 5; the remainder is banked for inclusion in a future seedlot because scores of these remaining clones were not available at the time the seedlot was registered.

Sitka Spruce Orchard and Crop Enhancement

A small crop was managed in the second-resistant Sitka spruce orchard at Saanich Forestry Centre. Supplemental mass pollination was applied. Cone yield was only 0.4 hl, and the seed yield amounted to 193 grams of seed with a resistance score of 88.

Treatments for foliar pests were applied. These treatments included applying pesticide for green spruce aphids in April, removing galls caused by spruce gall aphids in June, and applying pesticide for giant conifer bugs in June. The June application of pesticide is implicated in foliar damage. In future, we will not apply pesticide to soft foliage.

Yellow Cypress Production Hedges Enhancement

Enhanced management of the yellow cypress hedges resulted in delivery of cuttings material for 335,000 plantables to the 2007 nursery crop. The average genetic worth of this A-class material is 20.

Clone ecocentes from the field trials continued with transplanting 500 grafts in the hedging bed. Additionally, stock awaiting scores from the phase 4 and 5 trials were maintained. Fertilizer treatments were applied to enhance hedge production.

Yellow Cypress Clonal Sustainability Study

Studies continued in the rootability of clones, with two nurseries receiving material for the 2007 nursery crop. To date, trials are complete for 15 clones that have been tested three times in two crop years in a minimum of two nurseries. Of these, eight clones show high rootability, but one will be rogued because a subsequent score has lowered its rank, and plagiotropism displaced by a second clone has placed it for further testing. Six clones have shown consistently poor rootability and will be rogued from the production hedges for future vegetative lots. One clone has shown inconsistent rooting and will be further tested. Improving the rootability of the cuttings by improving the mixes to include only high-rooting clones will significantly reduce root rots at the nursery and will thereby improve the price of delivery of this high-gain material to planting programs. If this is successful, the current deployment of 50% wild seed in this seed planning unit will be dramatically reduced.

Figure 20. The Saanich Forestry Centre high-elevation western hemlock orchard was re-established after subsurface drainage was installed.

5.1.2 Sarchelli Seed Orchard

Pathi Screen

Douglas-fir

Due to a lack of induction response and a very wet, cold pollination period in 2006, only 7% of the original 300 induced trees had any cones left on them. These trees had been SMEP'd and were subsequently part of a trial to test new systemic insecticides.

In the high-elevation Douglas-fir orchard, 150 trees from orchard 110 were induced with $GA_{4/7}$ in late spring of 2006. This, together with the dry weather in late spring 2006, has resulted in a heavy crop year for this orchard in 2007.

Western redcedar

This project continues to maintain the redcedar ramets from test series 1 through 4 in the Seedling beds at Sechelt. In addition, 80 of the original age 20 Series 2 grafts were induced in the summer of 2006 with $GA_{4/7}$.

Pollen was collected from the top 20 percent of parents from Series 2 and supplied to 100 crop trees in orchard 100 in February/March of 2007.

Western white pine

WBLR pollen was collected from the WBLR identified trees in the Robert's Creek test site and supplied to all female cones produced in 2006 in orchard 174.

The 600 cone-producing ramets were monitored and spot treated for *Lygaeidae* control on a regular basis throughout the seed production season. Undeveloped cones attacked by *Lygaeidae* were collected and burned before the cone collection season for future control purposes.

5.1.3 MR Nanoose Seed Orchard (TimberWest)

Tim Crowder

Douglas-fir

SPU 0108 cones activities in four Silt M Low orchards (106, 056, 060, and 107. Orchards 114 and 154 are mature orchards that are rogued and upgraded as new ramets are available. Orchard 100 is a younger orchard that is in full production, while orchard 107 is in the establishment phase.

In 2006, because there was a small crop and the pollen cloud was light, SMEP was applied to all crop trees in all orchards, particularly early- and late-flowering clones. Cones were monitored for *Contorta* midge and other pests, and because infestation levels were high, all crop trees were treated with dimethoate using an air-blast sprayer.

Nearly 1,400 ramets were induced by stem injection of $GA_{4/7}$ to produce a crop in 2007. All four orchards were fertilized by injection through the irrigation system, and newly planted trees were top dressed with a granular fertilizer and hand watered as necessary.

In the fall, 300 young grafted ramets were transplanted into empty spots in the orchards.

In our grafting program we use large 2908 (#10) containerized root stock, which allows us to produce ramets that are ready for transplanting into the orchard within one year. Over 1,000 new ramets of high BV clones are being grafted in the fourth quarter of this project for future upgrading of the Douglas-fir orchards.

Western hemlock

SPU 0205 cones activities in two Cat M Low orchards (160 and 152). These two orchards are similar in composition and are typically induced in alternating years to provide a steady seed supply. In 2006, orchard 160 yielded over 2.4 kg of seed with a GEM of 47%.

Both of the color orchards contain large original ramets as well as small high-gain ramets from test series 1 and 2. One hundred of these younger ramets were induced by grafting with GA_4 for a crop in 2007.

Grafted ramets from test series 3 were maintained in a Seedling bed. Grafts from test series 4 through 8 were maintained in a potted Seedling area, then transplanted to a Seedling bed in the fall of 2006. A total of 2,100 grafts

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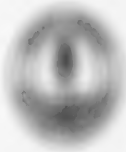

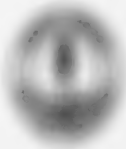

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At Orchids

- The purchase of battery powered pruners resulted in an increase in pruning efficiency and less strain on technicians' wrists and arms.
- Drainage installed at the top of Prince George orchard 233 will increase the health of ramets in the upper portion of the orchard.
- A weather station with updated software was installed in the Prince George Indigenous pine orchard. New software automatically calculates and plots degree day accumulation during the season. Data collected can assist in determining the effect of temperature on seed set, the timing of insect control, and trends over time.
- Foliar sampling and analysis were completed in all orchards. Sample results aid in determining nutrient application levels in the following seasons.

Available funding has a positive effect on the ability to achieve the Forest Genetics Council's goals of 1.2% gain and 75% use of Class A seed.

Species	Pest or Disease	Monitoring	Control Strategy
Pl	Lophodermium needlecast	Shoots: visual survey once a week	One application of Sevin
	Cytospora/Elytroderma	Pheromone traps and visual damage survey	Manual removal of young trees
	Dothistroma needlecast	Pheromone traps and visual survey's twice weekly	One to two applications of Sevin
	Needle rust	Twice a season	Cultural and chemical
Fd	Zeiraphera diniana/orana	Weekly cone survey	Two to three applications of dimethoate
	Adelges cooleyi	Spring survey	One application of Safer's Soap
Sx	Zeiraphera diniana/orana	Weekly cone survey	Two to three applications of dimethoate
	Adelges cooleyi	Spring survey	One application of Safer's Soap
	Cydia strobilella, Megastigmus sp. and Strobilomyia neanthracina	Spring cone sampling	Controlled with first application of dimethoate for Zeiraphera
	Oligonychus ununguis	Spring and fall surveys	Safer's Soap and Kelthane application
	Pissodes strobi	Visual survey	Manual removal

Table 7. Summary of the main pest and disease management initiatives undertaken at Vernon Seed Orchard in 2006.

Figure 22. Installing drainage in orchard 233.

5.3.7 Grandview Seed Orchards (PRT Armstrong)

by Hilary Graham

PRT Grandview manages five Lodgepole pine orchards and one Douglas-fir orchard, producing seed for the Thompson Okanagan (TO) low elevation and the Nelson (NE) low elevation seed planning units.

In 2006, all of the orchards received OTIP funding for activities to increase the yield and genetic gain of seed produced. These activities included grafting, bolting bed maintenance, planting of grafts, insect and disease monitoring and control, rodent control, crown management, foliar analyses, pollen monitoring, pollen collection, flower induction, phenological surveys, and supplemental mass pollination (SMP).

Pli orchards

To improve the quality of orchards Pli 308 (OTIP 10002), Pli 311 (OTIP 10001), and Pli 313 (OTIP 07002), 308 grafts were made and maintained in bolting beds. In the spring of 2007, we will plant our 185 grafts for orchard 308, 25 grafts for orchard 311, and 100 grafts for orchard 313. Fifty-six unproductive ramets were rogued from orchard 308. This provides for long-term increase in GW for all three orchards because the vacant positions are filled with higher gain material.

Pollen management activities began in early May with pollen collection, monitoring, and distribution using an orchard air-blast sprayer. Phenological surveys were conducted in the young orchards 337 (OTIP 07211) and 338 (OTIP 10007). These orchards, as well as the early- and late-flowering clones in orchards 311 and 313, received SMP applications. Pollen was collected from orchards 311, 313, and at the Kalamalka Forestry Centre. Whole pollen buds were collected both manually and by backpack vacuum by clone. Thanks to Michael Carlson and Chris Walsh for providing access to the Kalamalka clone banks. We collected five litres of pollen for the TO low orchards and three litres of pollen for the NE low orchards.

Foliar tissue samples were taken to determine the appropriate fertilizer mix for spring and fall applications. Throughout the season, we monitored all Pli orchards for insect, rodent, and disease problems. This ensured that measures were taken to protect ramet health and developing cones. Insecticide sprays were applied to control *Leptoglossus* seed bug. Fungicide sprays were required in the older orchards 308, 311, and 313. Poison baits were deployed to control rodents feeding on tree roots, and Pitch moths were removed by hand.

Fdi orchard

Pollen monitoring began at the first flight of pollen in the orchard. Pollen shed and female receptivity were monitored throughout the pollination period (phenological surveys) to determine the timing for SMP applications. The survey information also allowed us to identify and pollinate early- and late-flowering clones.

We applied stored pollen to receptive flowers three times (SMP). Pollen for future use was collected at the Kalamalka Forestry Centre. Thanks to Barry Jaquish and Valerie Ashley for providing access to the clone bank. Approximately 1.5 litres of pollen were collected, processed, and put into freezer storage.

Throughout the season, we monitored the Fdi orchard for insect damage to the developing cone crop. Insecticide sprays were applied to protect the crop from *Dioryctria* (the coneworm), which has caused substantial damage to previous cone crops.

We applied gibberellic acid (GA) to 675 ramets by stem injection. With the appearance of numerous developing female and male buds, we are very optimistic about the 2007 crop.

All projects were completed as planned in 2006. In the Pli Thompson Okanagan Low, we collected 12.15 kg of seed with the potential to produce 2.26 million seedlings. In the Pli Nelson Low, we collected 9.69 kg of seed with the potential to produce 1.81 million seedlings. The Fdi Nelson Low orchard produced 0.94 kg of seed with the potential to produce 42,188 seedlings.

The activities conducted in 2006 with the assistance of OTIP funding ultimately move us towards our goal of increasing the amount and quality of A-class seed for the Pli NE low, Pli TO low, and Fdi NE low seed planning units.

GRANDVIEW SEED ORCHARDS (PRT ARMSTRONG) INCREMENTAL PROJECTS

Crown management

With the purchase of highly effective pruning equipment, we carried out extensive crown management in orchards 308, 311, and 313 and removed unproductive central branches and long laterals that were encroaching on the sideways. We also removed some lower branches to expose

the boles for more effective MPB control. This pruning is expected to improve overall ramet vigour and encourage more cone-bearing sites. Only a portion of each orchard will be pruned each year to minimize the immediate loss of cone production.

Pollen management

To improve the ongoing pollen work in our Pli and Fdi orchards, the pollen laboratory at PRT required some upgrading. The purchase of a moisture analyser scale now allows us to complete pollen processing on site and get the pollen into freezer storage much more quickly.

Crop statistics

This project supported OTIP 0722, the "Collection of Crop Statistics for Interior Lodgepole Pine Orchards." Data was collected as outlined by project 0722 and cone samples were collected and delivered for analysis. We submitted standardized and summarized data related to cone production and seed yields from three of PRT's producing Pli orchards. The work will result in a better understanding of Pli seed production issues and will provide recommendations for improving orchard efficiency.

Gamete contribution

This is a companion study to support/complement the Pli seed orchard DNA fingerprinting project approved by the FGC. We collected pollen data during the 2006 pollination season according to the seedlot rating protocols used in all BC orchards (Woods 2005). In 2007 we will collect seed-cone data and ramet tissue samples for DNA analysis. Completion of this project will complement the FGC-funded DNA fingerprinting study and provide baseline data for comparing male and female gametic contribution protocols.

Figure 23. Crew applies pollen to Pli orchard 338.

Figure 24. PRT seed orchard staff in Fdi orchard 321.

5.1.8 Eagle Rock Seed Orchards (Tolko Industries)

Greg Pieper

The Tree Improvement Program supplied funding for work in our orchards. The goal this year was to fund activities to boost the quantity and quality of seed produced. We also collected pollen for future use.

SPU 16 Thompson Okanagan high-elevation Pli

- We were able to collect about 12 hectolitres of cones from this orchard this year.
- Because seed set continues to be a challenge, we used a helicopter and an airblast sprayer to distribute pollen and enhance pollen uptake for next year's crop.
- We collected 10 litres of pollen from orchard 310. Using Spritzers, we applied two litres of previously stored pollen and four litres from this year's collection.
- We expect approximately five hectolitres of cones from the new Pli orchard next year.
- Because height is a problem for picking, we did some top pruning on the old large ramets in orchard 310. We also did basal pruning to make it easier to operate equipment in the orchard and to increase light and air movement in the orchard.
- *Leptoglossus* was again a concern, and we used four sprays of Sevin to control them in 2006.
- We purchased battery operated Electrocoup shears for pruning.

SPU 28 to 30 Thompson Okanagan low and high -elevation Sx

- We selectively collected a good crop out of orchard 303 this year. We collected 48 hectolitres of cones containing 39,000 grams of seed with a maximum elevation of 1,650 meters. We rogued 83 ramets of poor genetic worth out of the orchard.
- Spraying was required for crop protection from *Leptoglossus*.
- We collected and stored 16 litres of pollen from orchard 303 for use in future years in the new 342 TO Low and 343 TO High orchards located at our site.
- We also topped trees in the new orchards to maintain low picking height.
- *Adelgids* were not a problem this year.

Figure 25. Collecting Pli using Girette.

5.1.9 Prince George Tree Improvement Station

Rita Wagner

SPU 1203, 1802, 1702, 4057E22, 4057E21

Activities are aimed at increasing the quantity and quality of lodgepole pine seed from Orchard 220 (Prince George low planning zone), Orchard 223 (Central Figureau low planning zone) and Orchard 228 (Bulkley Valley low planning zone).

Five Operational Tree Improvement Projects were conducted at the Prince George Tree Improvement Station in 2006-2007.

Phenology surveys were completed to identify early/late flowering clones. Pollen density was monitored both inside and outside the orchards.

Foliar samples were taken and analyses of nutrient status were completed in the fall.

Trees in all orchards were surveyed for western gall rust, lophodermella needle cast and root collar weevil. Extensive surveys were carried out due to a major mountain pine beetle attack in July 2006 and all three orchards were treated with Sevin to ensure survival of crop trees. As well, secondary bark beetles started to cause problems prior to MPB attacks (*Ips, Pityogenes, Pityophthorus*) and required some tree removal in orchards 223 and 228

The fall 2006 cone harvest from the three provenance orchards yielded 34.74 kg of seed and 6.95 million potential seedlings with a genetic worth of 6%.

SPU 1412

Management of interior spruce clone banks at the Prince George Tree Improvement Station is designed to ensure the availability of scion to replace existing orchard ramets or develop new orchards to boost productivity and gain.

The Interior Spruce Clone Banks at the Prince George Tree Improvement Station provide vital support to the orchard and tree breeding programs in B.C. The clone banks are a centralized source of scion material for the grafting of new and improved seed orchards. They contain the only copy of many of the interior spruce parent tree selections found in seed orchards and breed arboreta.

Clonebank fill planting was carried out to replace dead ramets and/or add new clones or increase number of live ramets per clone.

A total of 353 scion were collected at the Prince George clonebanks and grafted at Kalamalka seed orchard. 137 of these grafts were shipped to PGTIS and planted in our holding area in summer 2006. Kalamalka seed orchard is maintaining the remaining grafts until the grafts are a suitable size for transplanting into the clonebanks. Transplanting from our holding area into the various clonebanks was carried out. Remaining grafts in holding area were weeded, watered, fertilized, pruned and monitored and treated for insects and disease. Due to severe weather — thawing/freezing cycles plus strong winds — many grafts in the holding area and clonebanks died over the winter.

Similar management activities were carried out in the 12,000-tree clonebanks. Irrigation maintenance, fertilization, mowing and weeding will be required to ensure ramet survival. Foliar sampling was carried out. Insect (root collar weevil and spruce leader weevil) and disease monitoring was carried out to ensure ramet health. Ramet labelling was continued, replacing old, damaged tags and label newly planted trees with more permanent tags.

5.1.10 Skimikin Seed Orchards (Projects 404, 411, 501, 1503, 3502, 4002, 4057E13, and 4201)

Keith Cox

In 2006 we received funding for work in the research plantations, eight of the seed orchards, and to help deal with the Mountain Pine Beetle infestation at Skimikin.

In the West Kootenay (Nelson mid and high) spruce orchards, we planted 262 replacement grafts in the spring and made another 259 grafts in the holding area. We surveyed orchards for insects and disease, removed rust brooms (*Chrysomyxa arctostaphyli*), and baited rodents. Based on ten-year breeding values, we removed another 16 trees from orchard 301 and 31 from orchard 302, thereby increasing their average breeding values to ten and nine respectively. The trees will be hauled to the nearby Salmon River for stream-bank restoration.

We monitored the white pine orchard (609) extensively because of the mountain pine beetle, the conifer seed bug, and the pine cone moth. This monitoring activity resulted in a season total of 54 surveys. Pollen bud collection

yielded a total of 69 litres of pollen buds for supplemental pollination in orchard 335 at Bailey Road.

In the three spruce orchards for the Bulkley Valley Low, we sprayed the crop for spruce cone maggot and *Leptoglossus*. In orchard 208, we injected 305 trees with the flowering hormone GA in May and drought stressed them until the end of June. We repaired the ground where it had settled from previous roguing, and in April, we planted 529 replacement grafts in orchard 208 and made another 180 grafts. The crop was 4.6 hectolitres and yielded 3.8 kilograms of seed.

We monitored the 2,730 trees in the spruce orchard for the Peace River mid-elevation zone (212) for insects, disease, and rodents. We removed a total of 111 weevil-damaged tops and baited the young orchard extensively for rodents. In the spring, we planted 47 more trees in the orchard and maintained replacement grafts in the holding area.

In orchard 206, we did the final levelling where we had rogued 630 trees in 2005. We monitored the trees for insects and disease and sprayed them for spruce cone maggots and spruce cone rust. We removed rust brooms and baited rodents.

We monitored the on-site research plantations for insects and disease, baited them for rodents, and planted a second-generation spruce progeny test. We also planted approximately 3,000 white pine seedlings as part of a rust-resistance screening trial and prepared a site for more to be planted in 2007. We maintained the *Ribes* garden and inoculated white pine seedlings in September.

We monitored extensively for the mountain pine beetle, and to reduce the fire hazard, we cleaned up two areas by hand-piling and burning or mulching.

Figure 26. Squirrel activity in the unmanaged white pine orchard (607), Project 1503.

Figure 27. Temporary irrigation in the *Ribes* garden during white pine seedling inoculation, Project 411.

Figure 28. Burning to reduce the fire risk at Skimikin. Project 4057 E13.

5.1.11 Kettle River Seed Orchard

Rick Hansinger

POLLEN COLLECTION FROM KALAMALKA FORESTRY CENTRE FOR SMP IN YOUNG PG AND CP LODGEPOLE PINE ORCHARDS

Pli CP low – orchard size: 3,100 ramets

As part of this project, we collected, extracted, mixed, and moisture-tested 470 ml of pollen from KFS and completed BV calculation. We used 13 clones in the collection, with a weighted average BV of 10.89, and completed SMP on approximately 1,200 ramets with receptive female cones. Three complete passes were completed from May 20 through May 31. All pollen was used during SMP. A subsequent conelet survey in July has revealed that approximately 13,000 cones will be available for harvest in Aug. 2007.

Pli PG low – orchard size: 4,900 ramets

As part of this project, we collected, extracted, mixed, and moisture-tested 500 ml of pollen from KFS and completed BV calculation. We used 11 clones in the collection, with a weighted average BV of 9.78, and completed SMP on approximately 1,500 ramets with receptive female conelets. Three complete passes were completed from May 20 to 31 in order to ensure fertilization of early and late flowers. All pollen was used during SMP. A subsequent conelet survey has revealed that approximately 7,200 cones will be available for harvest in Aug. 2007.

Construction of Pollen Dryer

As part of this project, we constructed three pollen dryers, one for Kettle River and two for others (PRT and Sorrento).

The pollen dryers were constructed of marine-grade plywood, and all joints were glued and nailed to prevent airflow other than through the drying trays. The base was fabricated from steel-frame box tubing with lockable castor wheels for ease of movement. A variable-speed furnace motor draws outside air through selected vents and down through drying trays and exhausts out through a rear pipe vent.

Each dryer has nine drying bins with an approximate minimum capacity of 15 l of pollen. Sifting trays were constructed of stainless steel with 40, 80, and 100-mesh screens respectively. Each drying tray is supported with a plastic liner and silk-screen to prevent pollen loss during the drying process.

Summary

Pollen dryers have been used on an operational basis for Fd and Pl pollen at PRT and have operated effectively. No further design modifications are necessary. Tolko Industries purchased a pollen dryer from Kettle River in 2007.

5.1.12 Saanich Seed Orchard

Carolyn Lohr

Establishment and monitoring of regional pollen monitors on the Saanich Peninsula (SPU 0109)

We set up five seven-day recorders at locations throughout the Saanich Peninsula. The objective of this project was to provide consistent estimates of local pollen contamination to Joe Webber (ProSeed Consulting) for further analysis and ultimately to coastal Douglas-fir seed producers on the Saanich Peninsula in order for them to determine the effect on the genetic worth of Fdc seedlots. We monitored pollen flight from March 21 to May 1 (six weeks). We changed the charts weekly and counted, averaged, and forwarded the counts for two fields per day per chart to Joe Webber at ProSeed Consulting.

Orchard management operations to maintain productivity and increase gain in orchard 181 SM FDC (SPU 1902)

Orchard 181 is a 95-clone, 1037-ramet, first-generation SM, mid-elevation Fdc orchard. Fdc breeders planted progeny test plots in spring of 2005, and the initial rogue of the orchard will occur in 2008 (three-year data). The final composition of orchard 181 will consist of 25 to 30 clones from both forward and backward selections.

Management operations included surveying the health and vigour of the ramets as well as maintaining grafts, pruning rootstock, replacing mortality, applying fertilizer and irrigation, sampling foliar nutrients, surveying foliage and cones for pests, and applying dimethoate to control *Contarinia*.

Crop management included phenological and bud surveys, pollen collection, and SMP. Production for 2006 was 5 hl of cones and 2.34 kg of seed.

Pest management in high-elevation western hemlock orchard 196 (SPU 2403)

Orchard 196 consists of 24 clones on 251 ramets. The mean BV of this orchard is 11.

SPU 2403 covers pest management activities for cone and foliar insects in 196 orchards to retain the health and vigour of ramets. Orchard staff conducted weekly insect surveys and, in consultation with MFR seed pest management officer, determined that chemical pesticide applications were unnecessary. Active populations of Syrphid fly larvae kept hemlock adelgid populations under control for the 2006 growing season.

5.1.13 Sorrento Seed Orchards

Hilary Graham

Sorrento Seed Orchard manages two large Lodgepole pine orchards established in 2003 in partnership with Selectseed Company. These orchards will supply seed for the Central Figueroa (CF) low elevation and the Bulkley Valley (BV) low elevation seed planning units.

To initiate early seed production in these orchards, pollen management activities were conducted with OTIP funding in 2006. Pollen was collected at the Kalamalka Forestry Centre clone banks and used for supplemental mass pollination in both orchards in 2006. All conelets received up to three applications of pollen during their receptivity period.

As a result of this work, these orchards will produce seed in 2007. We will collect up to 1.26 kg of seed (250,400 plantables) with an expected genetic worth of 15% from the BV orchard. Approximately 760 grams of seed (150,000 plantables) with an expected genetic worth of 20% will be collected from the CF orchard.

Early seed production in these young orchards directly supports the FGC's goals by making more genetically improved seed available for use in BC's forests.

5.2 Technical Support Programs

5.2.1 Cone and Seed Pest Management – Interior Operations

Robb Bennett

This project covers operational expenses for the interior seed pest management biologist's activities, including all expenses associated with lab, field, and office work. Included in this project are wages for one co-op student (one term) and auxiliary technical support (as needed) to assist with operational pest management trials, data analysis, and development of new operational techniques. The pest management biologist position was vacant from January until the end of May 2006, when Jim Corrigan took over the position.

Between May 23, 2006 and 31 March 2007 the interior seed pest management biologist provided the following services.

1. Performed 90 site visits, pest surveys and identifications, and damage predictions and assessments.
2. Delivered 13 written pest status reports, position papers, and/or backgrounders for colleagues and superiors inside the Ministry of Forests and Range and for partners outside the Ministry of Forests and Range.
3. Prepared ~55 other extension recommendations, pest identifications, responses to requests for information, and other transfers of technology.
4. Dealt with ~40 requests for information from members of the public.

Work continued on in-house and collaborative development of protocols for seed bugs, seed wasps, cone worms, mountain pine beetle, and other insects of importance to interior cone and seed production. In summary, the interior pest management biologist:

1. Initiated, or collaborated with university, government, and other research personnel on, nine pest management projects in the field.
2. Assisted in the preparation of the 2006 mountain pine beetle risk assessment for PGTIS and Skimikin Seed Orchards.

3. Developed protocols for management of mountain pine beetle in interior BC seed orchards.

As well as providing training for orchard technicians, the interior pest management biologist provided the following training and educational opportunities:

1. Delivered five professional presentations for colleagues and was an invited speaker to a scientific symposium (Entomological Society of BC).
2. Delivered requested presentations to the Forest Genetics Council of BC, the Interior Technical Advisory Committee of the PGC, and BC Timber Sales.
3. Was featured in two newspaper articles and two radio interviews regarding 2006 mountain pine beetle infestations in the Okanagan Valley and participated in related educational activities at the Vernon Home Show and the Allan Brooks Nature Centre.
4. Made numerous "tail-gate" extension presentations to operational personnel.

The following publication resulted from this project:

Corrigan, J., M. Carlson, G. Giampa, V. Berger, C. Wiens, and W. Strong. 2006. They're baaaack! – observations of the first mountain pine beetle attacks recorded at the Kalamalka Forestry Centre. Tr-Talk 7(1):4-8.

5.2.2 Western Redcedar Pollen Monitoring, Saanich Peninsula

Joe Webber, Perfused Consulting

5.2.2.1 Introduction

The Chief Forester (CF) Standards for Seed Use in British Columbia has established the legal requirements for the use of tree seed on Crown land. For orchard seed lots, this includes effective population size (N_e) and genetic worth (GW). As well, where the risk of contamination exists, then the orchard managers must also include estimates of contamination. Calculations for estimating a seed lot's GW are provided by Woods et al. (1996), Stoehr et al. (2004), and Woods 2005. This includes both female and male gamete contribution (including non-orchard sources of pollen and SMP).

Currently, Woods (2005) lists only coastal Douglas-fir and lodgepole pine (Prince George) seed orchards as species for which managers must report contamination levels. However, the CF Standards also require managers to report levels of pollen contamination if an orchard is at risk. On the coast, this may include western redcedar, western hemlock, and Sitka spruce. This report covers the third year of monitoring western redcedar pollen flight on the Saanich peninsula and includes monitoring in two Saanich peninsula orchards (Western Forest Products and Timber West).

5.2.2.2 Methods

Seven-day pollen monitors (see Webber and Nance 1996) were used at each of five locations on the Saanich peninsula. The Ministry of Forests and Range, Tree Improvement Branch (Pacific Road) owned the monitors and changes the charts weekly. We also monitored western redcedar pollen in Western Forest Products (WFP) orchard 180 and Timber West orchard 140 at Mount Newton.

We counted two replicates on each chart and averaged the total number of pollen grains for the two replicates. We then divided by 48 mm² (the area of the chart counted) to represent the number of pollen grains per mm² for a 24-hour period. We then summed the daily pollen catch over the monitoring period to determine pollen load for 2007.

5.2.2.3 Results

Figure 29 shows the mean western redcedar pollen catch for five stations on the Saanich peninsula (figures for all five stations are available in the final report for SPU #262 2007). Figure 30 and Figure 31 show the mean daily pollen catch for two monitoring locations at WFP, the lower reservoir site adjacent to dish monitor 6 (Figure 30), and orchard 180 adjacent to dish monitor 9 (Figure 31).

The monitoring period for the Saanich peninsula was February 13 to March 19, 2007. However, western redcedar pollen flight effectively stopped March 8, and from then on we counted only red alder pollen (data not shown). Compared to the two previous years, the 2007 pollen load was about 107 (pollen grains/mm²/day summed over the monitoring period) compared to 53 last year and 138 in 2005 (Table 8). Daily pollen catch varied between orchard sites (Table 8), with the Agriculture Canada site producing the highest values and the Mount Newton site the lowest values for the three monitoring periods.

Figure 30 shows the daily pollen catch at the WFP lower reservoir site. This monitor was adjacent to WFP

debi monitor 6. Figure 11 shows the daily pollen catch in the WFP orchard 1991. The monitor was adjacent to WFP debi monitor 6.

The monitoring period was February 12 to March 14 since the monitor trials stopped for five days in orchard 1991 at WFP and February 11 to March 12 at TW. The receptivity period for WFP orchard 1991 was February 20 to March 8, and at TW it was February 16 to March 5. Table 5 shows the pollen load values for each of the three orchard sites, including the pollen load values calculated for WFP monitoring data for the two debi monitors (6 and 9). The 7 day monitor was adjacent to each of the debi monitors, and pollen load values for the 7 day was 39 compared to 100 at the reservoir site and 55 compared to 127 in the orchard. There are two important differences between these monitors. First the debis were located at 2 meters height whereas the 7 day monitors were placed at 5 meters height. Also the 7 day monitors are protected from the weather (upper), whereas the debis are exposed to the weather. Because this was the first time we compared side by side monitor trap efficiencies, it is too early to suggest that one is better than the other.

Figure 12 shows the daily pollen catch at the TW orchard 1991. The pollen catch values were similar to those observed at WFP but we do not have comparable data for TW western redcedar pollen monitoring.

[redacted]

The magnitude and range of western redcedar pollen on the Saanich peninsula is great as for any coastal species monitored. However, since western redcedar pollen is among the smallest (20µg) of all local conifers, the cone is counts will also be considerably higher than those for Douglas-fir, which is among the largest pollen grains of our local conifers (55µg).

A second difficulty in counting western redcedar pollen is its size and form. It is very similar to red alder pollen. Western redcedar pollen is about 25 to 30 µ in diameter with some warty structures (sculpture) on the grains. At x250 magnification, it is possible to identify redcedar pollen, but it is very difficult to separate it from red alder pollen. Red alder is slightly smaller (20 to 25 µ in diameter) with pores. It looks very similar to redcedar at x250 magnification but with smaller sculpture. Positively distinguishing the two species at x400 is possible (glass slide and cover slip). However, distinguishing the two species at x400 on the Vaseline coated sheets (no cover slip) is very difficult. In general, the two are separated on the basis of shape and phenotype. When they redcedar pollen is completely dispersed, and at x250, the redcedar appear as bright spots on the screen. Red alder is in general prolonged and the redcedar do not appear as bright spots. However, when the two mix, it is not possible to determine the source of either.

Separation of redcedar pollen from red alder was particularly difficult in 1989 and 1990 because there was considerable overlap of flowering periods. However, in 1991 there was a clear separation between the end of redcedar pollen shed (March 8 vs. 14) and the start of red alder pollen shed. All data shown in Figures 10-12 are for redcedar pollen only.

With the magnitude of pollen counts for western redcedar at both the monitoring sites, it is likely that significant contamination exists. This is certainly true for 1987 and 1988 when pollen counts were 2 to 4 times that observed in 1990. Whether this is a serious problem is not known. Certainly, any orchard clone stock with contaminated pollen should have a small positive effect on selfing. However, because the breeding value of contaminated pollen would be at best zero(0), any contamination will have a negative effect on higher breeding value clones.

This is the third year for monitoring western redcedar pollen shed from indigenous stands on the Saanich peninsula. However, the pollen monitoring techniques used for Douglas-fir may not be applicable for western redcedar. The actual monitors do an excellent job of capturing the pollen, but the clones coated with Vaseline make positive identification difficult even with compound microscopes using x250 magnification. Data collected for 1987 also shows that there are considerable differences between the total pollen catch for debis and the catch for 7 day monitors. This will contribute to substantial error when calculating contamination values for redcedar orchards on the Saanich peninsula.

[redacted]

[redacted]

Webber, J.E. and Namaro, R.K. 1990. Douglas-fir pollen management manual. 2nd Edn. Ministry of Forests and Range, Research Branch, Work. Pap. 02/1990. 35pp.

Woods, J.H., Stoehr, M.U., and Webber, J.E. 1990. Research for rating seed orchard seed lots in British Columbia. Ministry of Forests and Range, Research Program, Res. Report 90. 20pp.

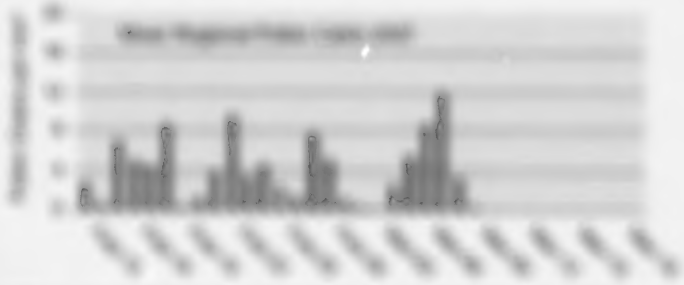


Figure 25 Mean daily pollen index 2007

Figure 26 Mean daily pollen index and daily pollen count for [illegible] 2007

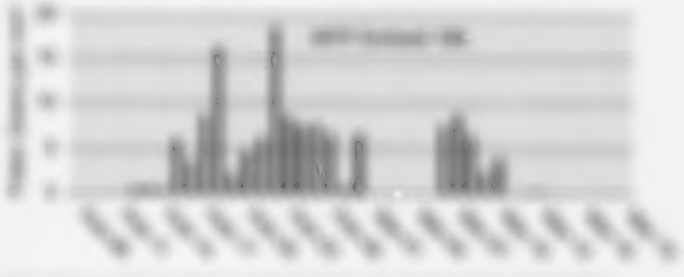


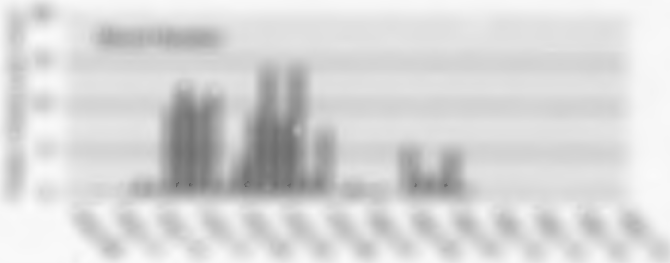
Figure 27 Mean daily pollen index and daily pollen count for [illegible] 2007

Monitoring location	2005	2006	2007
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

Table 24 Total pollen count (number of daily pollen counts) [illegible]

Monitoring Site	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

Table 25 Total pollen count (number of daily pollen counts) [illegible]



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5.2.6 Enhancing Seed Production in North Okanagan Lodgepole Pine Seed Orchards (SPU 0719)

Chris Walsh and Joe Webber

The OTIP SPU 0719 final report for 2005 provided a complete summary of the lodgepole pine seed set study for the period of 2000 to 2005. Over that period, the improved irrigation system did not result in substantial increases in seed yields, although cone mass and seed weights have improved. Temperature and drought conditions during the pre-pollination, pollination, fertilization, and embryo development periods have not been severe, and soil moisture content has been adequate. Crown misting has also not been necessary. Again, weather conditions during the sensitive periods of reproductive development have not limited either pollen uptake or fertilization and embryo development.

There is growing concern that both seed yields and cone numbers are declining over the last three years. This downward trend is observed across the orchard in general and is not associated with culture (over watering) although over watering may exaggerate this trend. Lower cone numbers may be the result of decreasing tree vigour caused by crown shading that comes from increased tree size. Also, cone numbers may be dropping because the sampling points have become increasingly lower in the crown. Although sampling now considers crown position (high and low), cone numbers are still declining.

We have no reason to suspect pollen supply (uptake) as the cause of the decline, especially in the upper crown seed cones, although pollen supply in the lower crown (in large trees) may be limiting. Since this orchard is nearing 20 years old, we must suspect the vigour of the trees as a cause of lower cone and seed production. We also need to consider whether insect damage to tree year cones after harvesting can adversely affect yields the following year.

Because the pre- and post pollination season was not hot and dry, we abandoned monitoring cultural effects on seed set. However, we monitored insect damage, pollen supply to lower crown cones, and weather. Increasing lower crown pollen supply (control crosses and SMP) did not improve seed set, and insect losses were in the range of 10 filled seed per cone in upper crown cones. We have noted that insect seed losses increase with heat. The year 2006 was relatively cool during the pre- and post pollination period but was unusually hot and dry during June and September.

RESULTS

Lower crown pollen supply

We used both control cross pollination and SMP to determine if pollen supply to lower crown cones was limiting seed yields. We treated lower crown cones with SMP in 2005 and then compared them with open-pollinated cones in upper crowns, both with and without insect protection (bagging). We compared cones treated with control crossing in the lower crown with OP cones in both the lower and upper crowns.

Figures 33 and 34 show the effect of SMP on lower crown cones for both total seed per cone (TSPC) and filled seed per cone (FSPC). Figures 33 and 34 also show the effect of insect protection on lower (SMP) and upper crown cones (OP only). Increasing pollen supply (SMP) to lower crown cones did not improve either TSPC or FSPC, but the effect of insect protection is apparent. About 10 FSPC were lost in the upper crown from insect predation, but the loss was less than two for lower crown cones.

Figures 35 and 36 show the effect of control cross pollination on lower crown cones compared to OP cones in both the upper and lower crowns. There was a slight decrease in FSPC (about four) from OP cones in lower compared to upper crown cones, and control cross pollination did not improve the number of FSPC in the lower crown.

Meteorological data

Temperature (Tsum) and vapour pressure deficit (VPDsum) sums are shown for the irrigation block only. Tables 13 to 16 show the meteorological data for four important periods of reproductive development in lodgepole pine. April to mid-May represents the period of equal second year cone development and pre-pollination development of the first year cones. The last two weeks of May represent the period of flowering, pollination, pollen uptake, and early pollen development (penetration of the nucellus). June represents the period of fertilization and early embryo development of the second year cones, and September is the period of differentiation of first year cones (although recent data on describing the period of seed cone differentiation suggest that it occurs much earlier).

Heat sums, vapour pressure deficits, and precipitation vary by year and period of reproductive development. During pre-pollination, 2006 was an average year with

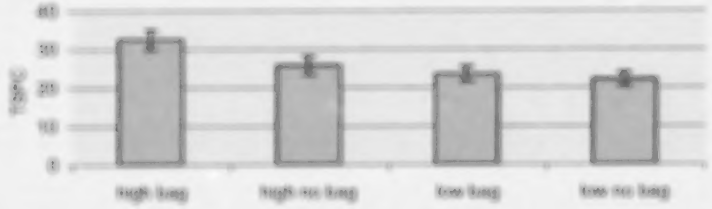

Figure 33. SMP on Lower Crown Cones Effect on Total Seed per Cone (TSPC).

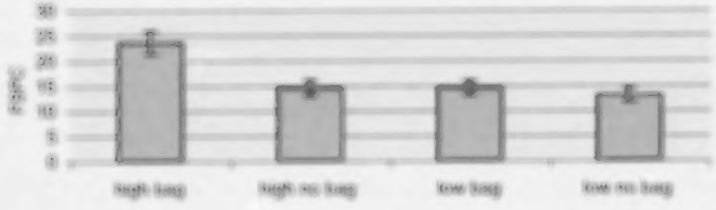

Figure 34. SMP on Lower Crown Cones Effect on Filled Seed per Cone (FSPC).

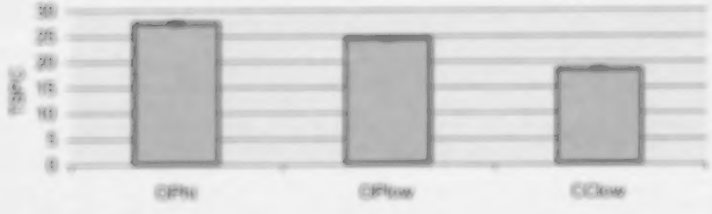

Figure 35. Control Cross Pollination on Lower Crown Cones Effect on Total Seed per Cone (TSPC).

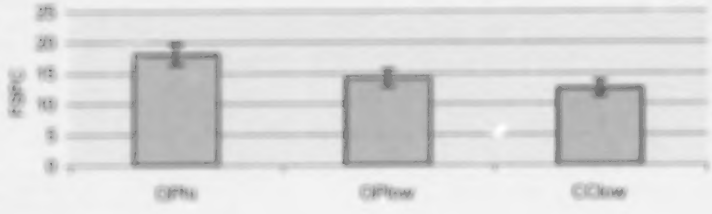

Figure 36. Control Cross Pollination on Lower Crown Cones Effect on Filled Seed per Cone (FSPC).

moderate heat and rain. This continued through the pollination period (Table 14), but the weather became very hot and dry in June (Table 15), and these conditions continued through to September (Table 16). September had the highest heat sums and VPD sums and the lowest rainfall recorded during the monitoring period of 2000 to 2006.

CONCLUSIONS

Increasing pollen supply, either by SMP or control cross pollination, did not affect seed yields (TSPC and FSPC) in lower crown cones. This suggests that pollen is not limiting in the lower crown. It is also possible that either pollen quality was poor or the pollination technique was not effective. Seed yields are typically lower in the lower crown, which may indicate a lower number of potential ovules. This may be a direct result of lower crown vigour, although crown position did not affect dry cone mass (data not shown).

Losses to insect damage were as great as ever observed. Weather conditions may explain the magnitude of seed loss to insects in 2006. Tables 15 and 16 clearly show that June and September 2006 were among the hottest and driest months since this data has been compiled (2000). About seven total and 10 filled seed per cone were lost in unprotected upper crown cones, whereas in the lower crown, less than two total and filled seed per cone were lost. These are important observations. In orchard 307 insect damage in the lower crown seems to be not a problem whereas in the upper crown, it is. If we are to improve seed set in this orchard, we must determine where losses in TSPC cones occur, and we must reconsider insect control technique.

	2000	2001	2002	2003	2004	2005	2006
Tsum	na	4740	3673	4400	5365	6480	4205
Tsum>24	na	299	74	48	456	1009	186
T>24 (hrs)	na	12	3	2	18	39	7
VPDsum	na	518	503	414	547	629	559
VPDsum2	na	39	45	28	67	130	49
VPD>2 (hrs)	na	17	20	13	29	55	21
precipitation	na	16.9	13.9	73.4	60.4	47.8	49.0

Table 13. Prepollination (April 15 to May 15).

	2000	2001	2002	2003	2004	2005	2006
Tsum	3466	4100	3603	3771	3631	4156	3905
Tsum>24	104	1515	304	48	578	1480	1148
T>24 (hrs)	4	54	12	2	18	51	41
VPDsum	313	424	283	414	283	407	349
VPDsum>2	23	163	50	54	67	178	146
VPD>2 (hrs)	10	56	22	22	29	58	49
precipitation	na	20.1	38.5	38.6	143.8	25.6	45.0

Table 14. Pollination (May 15 to May 31).

	2000	2001	2002	2003	2004	2005	2006
Tsum	8257	7591	10061	9896	9895	7906	9612
Tsum>24	2128	1495	5013	4443	4861	1116	3318
T>24 (hrs)	79	56	179	161	172	42	116
VPDsum	701	630	1056	887	882	509	983
VPDsum>2	209	161	595	443	444	84	459
VPD>2 (hrs)	78	63	202	161	154	35	143
precipitation	na	60.9	15.4	83.6	48.0	164.8	7.4

Table 15. Fertilization and early embryo development (June).

	2000	2001	2002	2003	2004	2005	2006
Tsum	5240	7617	7102	7773	5811	6092	9612
Tsum>24	328	1528	5014	1896	322	323	3318
T>24 (hrs)	13	58	179	68	231	13	116
VPDsum	345	672	660	681	297	437	983
VPDsum>2	22	178	123	211	11	28	459
VPD>2 (hrs)	10	72	47	75	5	13	143
precipitation	na	40.6	20.6	63.2	100.3	55.6	7.4

Table 16. Seed cone differentiation (September).

5.2.7 Increasing Quality, Genetic Gain and Quantity of Yellow Cedar Cuttings

Mark Griffin, John Ogg, Craig Ferguson, John Russell

SPU 1113

Introduction

This project involves increasing the quantity and quality of high-value yellow cedar cuttings for the coastal program. Objectives include:

1. provide the cultural treatments required to improve hedge production
2. enhance hedge composition by replacing lower-genetic-value families and clones with newly tested, improved clones

2006/2007 Highlights

Pruning of hedges occurred in early 2006, and fertilizing of both the soil-based and field-based container-planted hedges with 34-0-0, 19-18-18, and 12-51-0 continued throughout the growing season. The media for the greenhouse-grown container-planted donor plants contained APEX 16-5-11, augmented by weekly applications of hi-sol.

Approximately 5,400 genetically improved cuttings from series 1 and 2 with an estimated genetic worth of between 10 and 15% were potted up into one-gallon pots, pruned, and placed in a greenhouse to produce donors. These joined an existing inventory of some 4,200 donor plants. To create space for the newer, genetically improved material, 1,390 older series one selections were either rogued or moved out into the field. Some 1,560 genetically improved cuttings from SSM and QCI were also potted and placed into a greenhouse for production.

This year Cowichan Lake Research Station supplied BC Timber Sales with enough cutting material to set approximately 230,000 cuttings. Approximately 140,000 cuttings came from high-gain material from the greenhouse. The goal eventually is to produce 300,000 cuttings from the 8,000 high-gain greenhouse-grown donors.

Figure 37. Inventory of yellow cedar donor stock.

Figure 38. Older yellow cedar stock 5 weeks after mid-season pruning.

Figure 39. Younger yellow cedar donor stock 5 weeks after mid-season pruning.

Figure 40. Younger yellow cedar donor stock.

5.2.8 Effect of Selfing and Flowering Phenology on Seed Production in Yellow-cedar Seed Orchards. (SPU 1112)

Oldrich Hak

Results from a current study indicate that low-elevation yellow-cedar seed orchards are capable of producing viable seed (see Project Report 2004/2005). The study further shows that both low-elevation males and low-elevation females can produce viable seed. This is contrary to earlier reports that low-elevation seed orchards established on Vancouver Island are not able to do so. One possible answer to this discrepancy lies in the pollination method employed in each case. Open pollination was practiced in the early seed orchards at low elevation. Similarly, when open-pollinated cones were collected in the current study, they also produced empty seed. However, when control pollination was used, the cones produced viable seed. There was an abundance of pollen on the tested trees and on surrounding trees for open pollination. This suggests that there may be several unknown and untested factors responsible for this failure.

The objective of this project is to test three possible causes for empty seed production in open-pollinated seed orchards: selfing, flowering phenology (timing of natural pollen shed vs. timing of the receptivity of female flowers) and insect damage.

The study is being carried out at two locations at two different time periods. The first trial was initiated at the Mount Newton seed orchard in spring 2005, and the second trial was initiated at the Western Forest Products seed orchard in spring 2006. Pollinations were completed at Mt. Newton in winter 2006, and at Western Forest Products the pollinations will be done in winter 2007. Cones will be collected and seed will be extracted one year after pollination; the percentage of full seed for each treatment will be determined.

5.2.9 Crown Pruning Technique for North Okanagan Lodgepole Pine Seed Orchards. SPU 0720

Chris Walsh and Joe Webber

As orchards mature, crown form eventually becomes either too high or too bushy to manage effectively. In general, trees taller than 5 to 6 m require some form of topping and also pruning of lateral branches that extend into the rows to allow access for tractors and pickers. Experience from applying other pruning treatments to lodgepole pine suggests that cone production (both seed and pollen cones) will drop immediately after pruning but can return to pre-treatment levels within three to five years.

Most north Okanagan lodgepole pine seed orchards are now at the age where they require crown management activities. Lodgepole pine seed orchard 230 at Kalamalka was chosen for a pruning trial starting in 2004 because the trees were then at an age (12 to 15 years) and height (4 to 6 m) at which crown management must be considered. This project is testing three levels of height control: control (no topping), moderate (3.5 to 4.0 m) and severe (2.5 to 3.0 m), in addition to two levels of lateral pruning: tractor (remove only laterals extending into the row) and picker (remove extending and upper-crown laterals to improve crown access). We measured tree response to crown-pruning treatments initially in 2004 and subsequently in 2005 and 2006.

Results

A complete analysis of all data is available in the final report for OTIP SPU 0720, distributed to all Pli orchardists. This report summarizes the data from 2004 to 2006 for cone counts (whole tree and branch counts) and seed yields (high and low crown, with and without insect protection).

Cone counts

Figures 41 and 42 show the mean whole-tree seed-cone counts for each of the three pruning blocks and for the levels of treatment in the three pruning blocks and two lateral-pruning sub-blocks. Cone counts dropped (Figure 41) the first year after pruning (existing first-year cones removed in 2004) and substantially increased in 2006. Note that because the 2006 cones were already formed in the remaining branches after pruning in the late fall of 2004, we do not expect pruning regimes to affect these counts dramatically until 2007. However, it is interesting to observe that cone counts for the moderate pruning level are the same as for the control block, and, as expected, cone counts in the severe block are substantially lower.

Seed-cone counts also varied by levels of topping and lateral pruning (Figure 42). There were substantially more cones in the picker-access sub-blocks of both the control and moderate top-pruning blocks, but not in the severely pruned block. We observed this trend in 2004 and again in 2006.

Figure 43 shows the mean seed-cone counts for a major whorl branch in the upper and lower crown. As expected, there were two to three times more cones in the upper

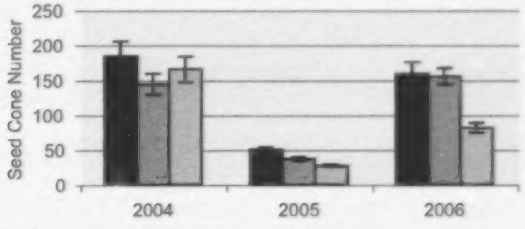

Figure 41. Mean whole-tree seed-cone counts for each of the three pruning blocks.

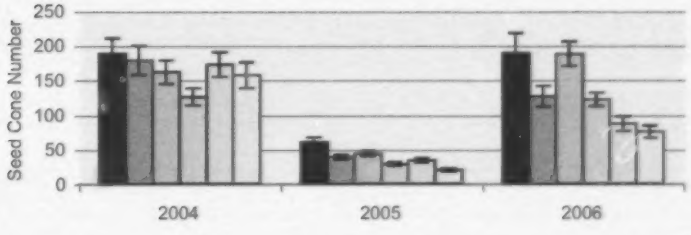

Figure 42. Mean whole-tree seed-cone counts for treatments in pruning blocks.

crown. If crown pruning helps to re-invigorate the lower crown, then we may expect lower-crown cones to increase relative to the control block.

Seed yields

Figures 44 and 45 show the mean total seed per cone (TSPC) and filled seed per cone (FSPC) for the three top-pruned blocks. TSPC and FSPC both declined in the year following pruning (2005) and increased slightly in 2006. Although we would not expect pruning treatments to produce substantial differences in cone yields, there is a small, positive indication that yields in the moderate and severe pruning blocks were higher in 2006. This result may indicate that re-invigorating the crowns by top-pruning improved seed set. We will closely follow this result in the next few years.

Figures 46 and 47 show the FSPC data from the three top-pruned blocks by lateral-pruning (Figure 46) and by crown height (Figure 47). Again, FSPC values were slightly better in the top-pruned blocks, but they were unaffected by lateral pruning. It is too early to determine if this is a trend or just a yearly variation. Again, subsequent years' observations will determine if this is a trend.

Figure 47 shows the difference in seed yields by crown position. Yields were higher for upper-crown cones, but the magnitude of the difference was smaller for the moderate and severely pruned bocks. Again, this may indicate that lower crowns of top-pruned blocks are more vigorous.

Finally, Figure 48 shows the differences in seed cone yields by insect protection for each of the three topping blocks. Although seed loss to insect predation is not necessarily associated with top-pruning treatments, this data clearly shows that seed losses in 2006 were in the order of 10 FSPC. In the two Kalamalka lodgepole pine seed orchards, insect damage in 2006 was among the highest ever recorded.

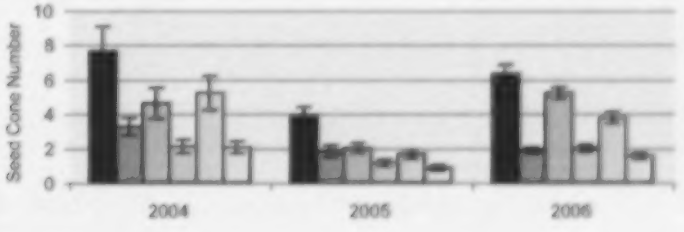

Figure 43. Mean seed-cone counts for a major whorl branch in the upper and lower crown.

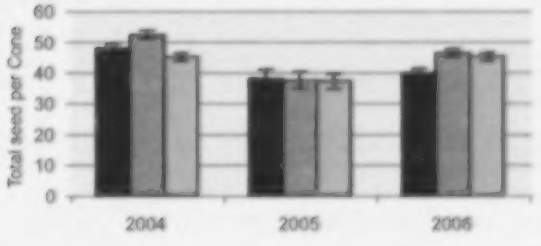

Figure 44. Mean total seed per cone (TSPC).

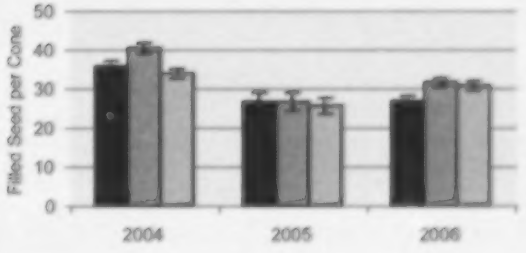

Figure 45. Filled seed per cone (FSPC) for the three top-pruned blocks.

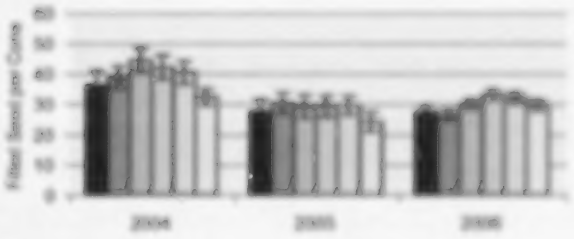

Figure 46. Filled seed per cone data from the three top-pruned blocks by lateral-pruning.

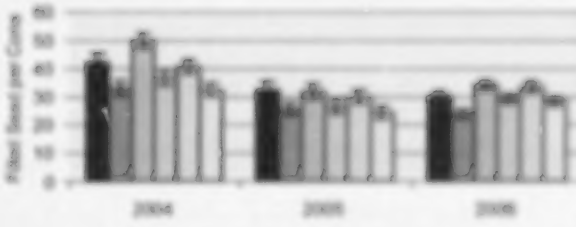

Figure 47. Difference in seed yields by crown position.

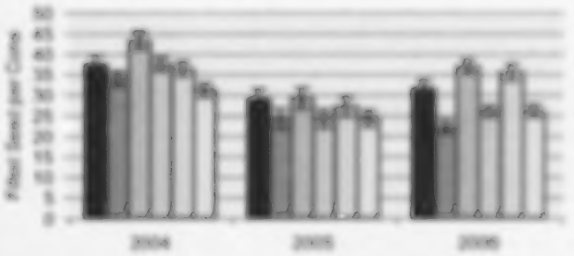

Figure 48. Differences in seed cone yields by insect protection for each of the three topping blocks.

5.2.10 Western Hemlock/Sitka Spruce Pollen Monitoring, Saanich Peninsula

Joe Webber, ProSeed Consulting

Introduction

The Chief Forester (CF) Standards for Seed Use in British Columbia (2006) has established the legal requirements for the use of tree seed on Crown land. For orchard seed lots, this includes effective population size (Ne) and genetic worth (GW). Calculations for estimating a seed lot's GW include female and male gamete contributions, including non-orchard sources of pollen (contamination). The CF Standard defines pollen contamination as "pollen, originating from a natural stand outside a seed orchard that contributes to the pollination of female cones on parent trees in the orchard." Appendix 4.2 (item 4) of the CF standard requires that the question of whether pollen contamination is present or not (Yes or No) be asked. If Yes, then item 7 requires that the proportion of contaminate pollen and the methodology used to calculate percent contamination be reported.

Currently Woods (2005) lists only coastal Douglas-fir and lodgepole pine (Prince George) as orchard locations at risk from contamination. Woods (2005) suggests that other coastal species such as western hemlock, western redcedar, and Sitka spruce may also be at risk, and as data are provided, one or more of these species may be added to the list of coastal species at significant risk.

This report summarizes the extent (duration of pollen flight) and magnitude (pollen cloud density) of western hemlock and Sitka spruce pollen flight on the Saanich peninsula for the pollination period of 2006 and compares this data to the pollen flight data collected in 2005. A

complete report on pollen capture at all five stations for 1996 and 97 for 2006 is available for project SPU-0513-(2006) from the OTIP coordinator.

Methods

The statutory standard for monitoring pollen cloud density uses seven-day recorders (see Webber and Painter 1996) mounted on rotating platforms at 3 m height. Daily pollen catch was expressed as the number of pollen grains per cm². Five pollen monitoring stations were used in the Saanich peninsula, which corresponds to the same stations used by the Ministry of Forests and Range, Tree Improvement Branch, for their annual regional pollen monitoring of coastal Douglas-fir pollen. Bruce MacPherson (Mid-Coastal Seed Orchards) was responsible for maintaining the five Saanich peninsula monitoring stations (erecting monitors, changing charts).

We counted two replicates on each chart for a 24 hour period and averaged the total number of pollen grains for the two replicates. To determine the pollen cloud density, we then divided the average daily counts by 44 mm² to represent the number of pollen grains per mm² for a 24 hour period. We also compared results for regional monitoring of western hemlock and Sitka spruce pollen flight with the receptivity periods and pollen cloud density values monitored at the Western Forest Products (WFP) Saanich seed orchard site (five orchard 170 and Six orchard 172).

Results

Figure 49 shows the daily western hemlock pollen cloud density values averaged over the five Saanich peninsula stations. Figure 50 shows the daily Sitka spruce pollen cloud density values averaged over the same five stations.

In 2006, the mean western hemlock pollen shed on the Saanich peninsula ranged from March 24 to April 30. The period of Sitka spruce pollen shed was April 14 to April 30 (the end of regional monitoring, although WFP orchard 172 continued to shed for one more week). Table 17 shows the total pollen load for western hemlock and Sitka spruce in years 2005 and 2006. Pollen load represents the daily pollen cloud density summed over the monitoring period. Compared to 2005, pollen capture for the western hemlock and Sitka spruce was about 20 percent and 50 percent lower, respectively, than in 2005.

The total regional pollen load (mean for all five stations) for western hemlock and Sitka spruce for the six week monitoring period was 9.2 and 1.9 and 1.6 and 0.8 pollen grains/cm² for each of 2005 and 2006, respectively.

Although the corresponding values for pollen load for the receptivity period of WFP orchards 170 and 172 are not strictly comparable (daily counts versus seven-day recorder counts), we can still estimate potential western hemlock pollen contamination from daily counts taken within the orchard and regional counts from the Saanich peninsula. Table 18 shows the pollen load (mean for all five stations) from regional counts during the receptivity period 2005 and 2006.

The corresponding pollen load values (regional) for western hemlock and Sitka spruce were 1.3 and 1.0 and 0.3 and 0.7 grains/cm², respectively. Table 19 shows the corresponding values for pollen load (orchard) summed over the receptivity period of western hemlock orchard 170 and Sitka spruce orchard 172 (slides).

According to Woods et al (1998), regional pollen capture for the receptivity period of the orchard is adjusted for the difference in capture efficiency between the regional monitors (seven-day) and the orchard monitors (slides). The orchard adjustment factor (OAF) is determined by averaging the ratio of daily pollen capture of the orchard slides to the regional seven-day monitors. Thus, by averaging the early orchard pollen capture (EOR) to the early regional average (ERA) for a period of seven to ten days (prior to orchard pollen flight), a factor is calculated that can be applied to the regional counts for the orchard receptivity period. However, in practice the calculation of the OAF has been inconsistent. Often there are not enough days prior to orchard shed to give a reliable result (regional shed and orchard receptivity period overlap). Because of this, the OAF was not considered in the following calculations of pollen contamination. Table 20 shows the estimate of pollen contamination for both western hemlock and Sitka spruce using only the regional pollen counts and orchard counts.

Conclusions

For both 2005 and 2006, the pollen counts for western hemlock were lower than those observed for Douglas-fir and significantly lower for Sitka spruce. For example, regional pollen loads for the six week monitoring period for Douglas-fir in 2005 and 2006 was 18.3 and 15.0 grains/cm², respectively. This corresponded to an estimate of pollen contamination (no OAF) of 4.8 and 12.3, respectively. The estimates of contamination based on pollen monitoring have also been confirmed in Douglas-fir with DNA paternity analyses. For the two years of

2005 and 2006, the corresponding values for percent contamination were 0.7 and 11.7. These are in close agreement with pollen monitoring data.

Since pollen monitoring data can give a good estimate of contamination, we can infer that contamination in western hemlock orchards on the Saanich peninsula does occur and that the value of contamination for 2005 and 2006 could be in the 10 to 20 percent range. With this limited data, we cannot predict if future contaminant pollen clouds will be greater. Certainly we can expect that orchard pollen clouds will be greater as the orchard trees mature.

It is more difficult to infer the same for Sitka spruce. Because the number of pollen grains captured is so small, the error in the estimate is much higher. Furthermore, we do not anticipate that the regional pollen cloud density for Sitka spruce will be any greater than what we have observed in 2005 and 2006 (local population is so small), but we can anticipate that the orchard pollen cloud for Sitka spruce will increase as the orchard matures. Because of this, we may consider that contamination is not an issue for Sitka spruce orchards on the Saanich peninsula.

Stevenger, J. 2009. Chief Forester's Standards for Seed Use. BC Ministry of Forests and Range, Victoria, BC.

Steeves, M., Webber, J., and Woods, J. 2004. Protocol for rating seed orchard seed use in British Columbia: quantifying genetic gain and diversity. For. [illegible]

Webber, J.E., and Painter, R.A. 1999. Douglas-fir pollen management manual. 2nd Edn. Ministry of Forests and Range, Research Branch, Work. Pap. [illegible]

Woods, J.H., Steeves, M.G., and Webber, J.E. 1998. Protocols for rating seed orchard seed use in British Columbia. Ministry of Forests and Range, Research Program, Res. Report 08. 20pp.

Woods, J. 2005. Methods for estimating genetic contributions to orchard seed crops and regional use in British Columbia. BC Min. For. Range, Res. Br., Victoria, B.C., Tech. Rep. [illegible]

Figure 46 Mean daily western hemlock pollen cloud density values (pollen grains/cm² /24 hours) for five Saanich peninsula monitoring stations (2006). Black data points represents the receptivity period of MKP for orchard 114.

Figure 47 Mean daily Sitka spruce pollen cloud density values (pollen grains/cm² /24 hours) for five Saanich peninsula monitoring stations (2006). Black data points represents the receptivity period of MKP for orchard 114.

	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

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5.2.11 Enhancing Lower Crown Vigour and Cane Production in Mature Lodgepole Pine Seed Orchards

[illegible]

Introduction

[illegible]

Procedures

[illegible]

[redacted] [redacted] [redacted] [

[redacted]

[redacted]

[redacted]

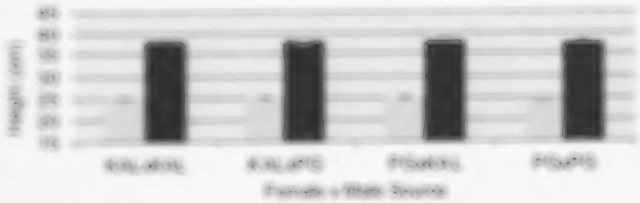
Height growth

Figures 57 and 58 show the mean height growth (cm) for all progeny from each of the four parent sources. At the WKNSA site (Figure 57), the PG x PG source grew tallest; the difference was less than 1 cm compared to the KAL x KAL source. Growth at PGTIS was significantly less (111 cm compared to 95) with the PG x PG source also growing tallest, but again the difference compared to the KAL x KAL source was about 1 cm.

The reciprocals were slightly shorter. PG females crossed with KAL males grew the shortest at WKNSA, while at PGTIS, the KAL females crossed with PG males grew the least. While these differences may have biological significance, they are not sufficient to change our current deployment strategy.

Conclusion

While the progeny from Vernon suffered more damage the first year after planting, parent source had little effect on years later on height. Our objective for this project was to determine if parent source affected bud burst and/or height growth. Data collected in 2006 suggest that growth may be slightly different depending on parent source. While this may have biological significance, it does not have any operational significance. This data also suggest that orchard seed from the north Okanagan is as well adapted to Prince George planting sites as seed from Prince George.

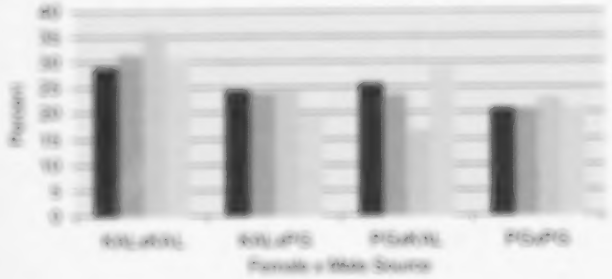


2006
2007

Figure 57. First- and second- year heights for the seed orchard aftereffects plantation (PGTIS).

2006
2007

Figure 58. First- and second- year heights for the seed orchard aftereffects plantation (WKNSA).



none
>50%
<50%
dead

Figure 59. Percent seedling damage at the WKNSA plantation after the first winter by damage class and female x male parent source.

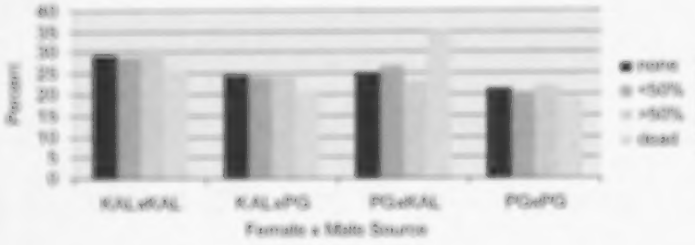


Figure 54. Percent seedling damage at the PGTIS plantation after the first winter by damage class and female x male parent source.

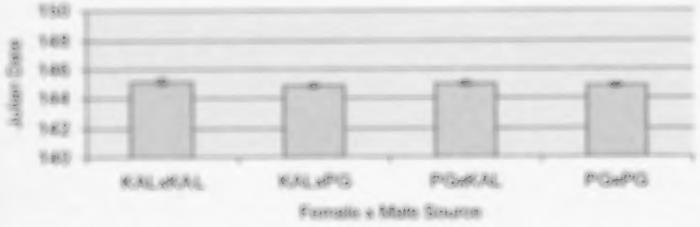


Figure 55. Mean (± standard errors) Julian date of bud burst for the WANSA plantation for each of the four female x male parent sources.

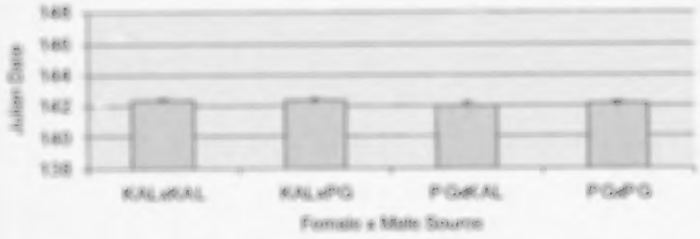


Figure 56. Mean (± standard errors) Julian date of bud burst for the PGTIS plantation for each of the four female x male parent sources.

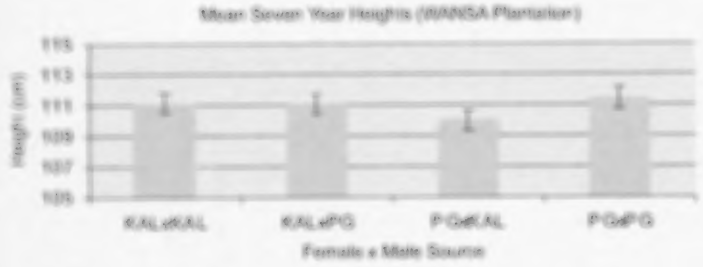


Figure 57. Mean (± standard errors) height growth (cm) for the WANSA plantation for each of the four female x male parent sources.

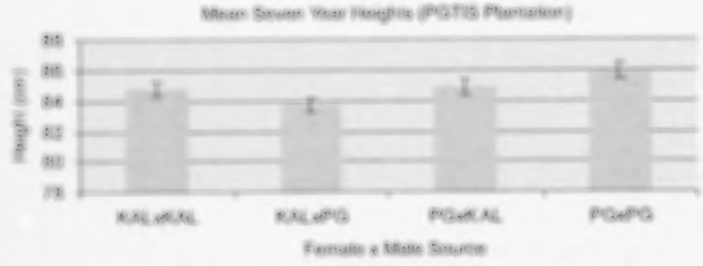


Figure 58. Mean (± standard errors) height growth (cm) for the WANSA plantation for each of the four female x male parent sources.

	Damage Class	Number of Seedlings	Female/Male Parent Source KAL/KAL	KAL/PG	PG/KAL	PG/PG
WANSA	none	8400	29.1	24.3	25.8	20.9
	<50%	1024	31.4	24.0	23.6	20.9
	>50%	180	36.1	24.4	16.7	22.8
	dead	232	30.6	19.4	28.9	21.1
PGTIS			KAL/KAL	KAL/PG	PG/KAL	PG/PG
	none	1086	29.1	24.5	25.2	21.2
	<50%	5906	28.9	24.0	26.7	20.4
	>50%	2803	31.0	24.2	22.9	22.0
	dead	43	25.6	20.9	34.8	18.6

Table 22. Percent seedling damage after the first winter by damage class and female x male parent source.

5.2.13 Development of Pollen Quality Guidelines for Pollinations in Western Redcedar Seed Orchards. (SPU 0213)

Oldrich Hak

The objective of this project is to develop pollen quality guidelines based on the relationship between pollen quality (viability) and the percentage of filled seed produced.

Pollen collection, processing, and storage are required for control and supplemental mass pollinations in western redcedar seed orchards. Because of its small size and limited food reserves, western redcedar pollen is exceptionally susceptible to damage from premature pollen collection, adverse temperature, and humidity conditions during processing, and adverse storage conditions. As a result, there is a wide range in pollen quality among various collections used for pollination.

Establishing a relationship between pollen viability and the percentage of viable seed produced will resolve the question of the levels of pollen quality (i.e., % of pollen viability) at which unacceptable numbers of filled seed is produced (i.e., when the percentage of filled seed is zero or very low).

The study was established at the Cowichan Lake Research Station and at the Mount Newton Seed Orchard in Saanichton (Timber West). Stored and freshly collected pollen will be tested for viability using solid media germination technique.

In the first year, approximately 50 pollen lots with various levels of viability, ranging from 0% to 90%, will be used to control pollinate female flowers. Each pollen lot will be tested on two different clones with two control crosses per clone to a total of 200 control crosses. Approximately 40 trees (clones) will be needed for the control pollinations because several different crosses can be done on each tree. Male cones will be picked away from females on selected branches, and each branch will be isolated with a pollination bag. Each tree will be monitored frequently for female receptivity (i.e., pollination drops). There will be two pollinations per cross. Pollination bags will be replaced later with insect bags.

Cones will be monitored for development and collected in the fall. Collected cones will be dried, and seed will be extracted and cleaned. Three samples of 100 seed per sample will be taken from each cross, and cutting and examining each seed will determine the number of filled and empty seed. The percentage of filled seed per cross will be calculated.

Collected data will be used to show in graph form the relationship between percent of pollen germination and percent of filled seed.

5.2.14 Conducting a Series of Soil Tests in the Kalamalka Larch Seed Orchards to obtain a Baseline Indication of the Levels of *Pythium* and *Fusarium* (SPU 1303)

Gary Giampa

Objectives

In 2005 Kalamalka lost almost five percent of the ramets in our larch seed orchards. The trees were either very productive mature ramets or new transplants with a high breeding value. An investigation by Michael Peterson of Applied Forest Sciences indicated the possibility that pathogen levels in the soil were high enough to cause a disease threat. If we can determine levels of *Pythium* and *Fusarium* present in the orchards, our management techniques can be modified to maximise ramet survival and maintain seed production levels.

Activities

In order to obtain a baseline indication of the levels of *Pythium* and *Fusarium*, we made a series of soil tests in transects across the seed orchards. The samples were then analysed for pathogens. The samples were collected in the spring, summer, and fall of 2006.

Results

These tests indicated that levels of soil-borne *Pythium* and *Fusarium* fungi in both Kalamalka larch seed orchards were significantly higher than levels that are commonly believed to lead to disease conditions.

	spring	summer	fall
Pythium propagules per gram average	1834	5545	2271
Fusarium propagules per gram average	3458	9033	3047

Table 23.

Output and deliverables

It is impossible to state conclusively that these high pathogen levels are causing the mortality in the Kalamalka larch orchards, but the levels are a concern. In 2007 we intend to test several different irrigation regimes in our larch orchards in an effort to reduce these high levels of harmful pathogens. We will collect and analyse soil samples to determine the response of the *Pythium* and *Fusarium* fungi to various watering treatments.

5.2.15 Collection of Crop Statistics for Interior Lodgepole Pine Orchards

Prepared for Michael Carlson by Joe Webber, ProSeed Consulting

The Lodgepole Pine Task Force met on January 25, 2006 (VSOC) and determined the need to develop methodology for making comparisons among producing lodgepole pine seed orchards. The underlying concern is that seed production from north Okanagan orchards is significantly less than expected. To determine the source of these losses and make recommendations for orchard management practices to improve seed production, the task force required standardized collection of data for all producing orchards. This project developed standard methods for estimating the number of cones per tree based on cone weight, and for estimating cone yields (filled seed per cone, total seed per cone, seed weight), pollen cloud density, and seed losses from insect predation. As these data are collected over several years, trends in yearly variation in cone numbers and seed yields will help determine why seed set in the north Okanagan lodgepole pine seed orchards is chronically low. A summary of the methodology and results for OTIP project 0722 follows. A detailed final report for SPU 0722 (2006) is available from the OTIP coordinator.

In the spring of 2006, 15 trees (clones) were selected to include both early, mid- and late-flowering clones. The number of cones per tree was estimated by weighing a known number of cones and the total number of cones per tree. This method removed a source of error that resulted from estimating cone numbers per tree by volume. Figure 59 shows the data for the 15 selected trees (+/-

standard errors) for each of the 12 lodgepole pine orchards monitored in 2006.

Kalamalka produced the highest number of cones (both orchards) and Prince George, as expected, produced the fewest. However, any further comparison would be difficult because we do not have data for crown volume and tree age. Collecting this data for 2007 may be very helpful.
All data represent one ramet of each of 15 producing clones. The method may not capture the variation in per tree seed production among ramets of a clone, nor does it include typically unproductive clones. However, the 15 trees do allow relative comparisons between orchards for total seed produced per tree. Data shown in Figure 60 were calculated using the number of cones per tree (Figure 59) multiplied by the number of filled seed per cone (Figure 62) determined for the 30-cone sample. Averaged over all 12 orchards, the mean seed production per tree was about 3,200 and the range was 1,057 (ER 310) to 7,155 (KAL 230).

Cone mass varied among orchards, but there was no relationship between dry cone mass and seed yields. Further, there was very little variation among orchards (data not shown).

Cone yields varied considerably, however. Figures 61 and 62 show the total seed per cone (TSPC) and filled seed per cone (FSPC) respectively for the 30-cone sample from the 12 selected orchards. Figure 63 shows the percent filled seed per cone (FSPC/TSPC*100).

Figure 61 shows the total seed per cone (TSPC) for all 12 orchards. Prince Gorge consistently produced the highest values (all above 30), but KAL 230 and PRT 313 also produced above the 30 value. All the rest were 20 or fewer. Since lodgepole pine should have between 30 to 40 potential seed per cone, we must try to explain where the 10 or more TSPC are lost. Since insect bagging occurred between the second and third week of April, we may infer that insect predation on unprotected cones may have affected ovules development (leading to fewer TSPC) as well as lower filled seed per cone later in June. Inefficiencies in extraction (tumbling) may account for a few TSPC losses, but this should be reasonably consistent across all orchards.

For example, only 10 TSPC were extracted from ER 310 cones. Were there fewer ovules producing fewer potential seed? Was the pollen cloud limiting (not according to data shown in the final report)? Was insect damage a cause (about 10 TSPC were lost when insect-bagged cones were compared to unbagged cones: see Figure 64). We certainly understand how insect (*Leptoglossus*) damage can lower FSPC, but it is not obvious how insect-protected cones produce about 10 more TSPC.

Filled seed per cone (Figure 62) follows a similar trend to TSPC. Again Prince George produced the highest FSPC (all above 20 FSPC), and Kalamalka 230 produced the highest values (19.4) for the north Okanagan orchards. Excluding Kalamalka 230, PRT 313 produced the highest (16.1 FSPC) yields of the north Okanagan orchards, with FSPC for the remaining orchards ranging between 4.8 and 12.2.

Figure 63 shows the percent filled seed per cone (FSPC/TSPC*100). All Prince George orchards are near or greater than 70 percent. Since we assume that cone development at Prince George is normal, our target for north Okanagan orchards should be similar. Average percent FSPC for all the north Okanagan orchards was less than 50 percent (47.1). However, this statistic is somewhat misleading because both TSPC (Figure 61) and FSPC (Figure 62) are lower than expected. If mean TSPC (Figure 61) were about 10 higher, then percent FSPC would be considerably lower.

One of the principal causes of the loss of seed in the north Okanagan lodgepole pine seed orchards is insect predation (*Leptoglossus*). However, it has been difficult to quantify these losses across all orchards because both monitoring of the damage (insect bagging) and control measures varied considerably. This year, all orchards followed standardized procedures for monitoring insect damage.

Figures 64 and 65 show the cone yields (TSPC and FSPC, respectively) for insect-protected cones (bagged) and unprotected cones (unbagged). Figures 66 and 67 show the differences between FSPC and TSPC for bagged and unbagged cones respectively.

Data (TSPC and FSPC) for unprotected cones shown in Figures 64 and 65 are similar to the data shown in Figures 61 and 62, which are based on the 30-cone sample. To determine the magnitude of the differences in TSPC and FSPC between bagged and unbagged cones, Figures 66 and 67 show the mean difference for each of the 15 trees in each of the 12 orchards. The heaviest loss of TSPC occurred at Kalamalka. Greater than 15 TSPC were lost at Kalamalka from unprotected cones compared to insect-protected cones. Eagle Rock lost about 12 TSPC, and the remaining orchards lost between 5 and 10 TSPC.

Loss of filled seed in unprotected cones also followed the same trend observed for TSPC. No significant differences were found for the Prince George orchards (no *Leptoglossus*

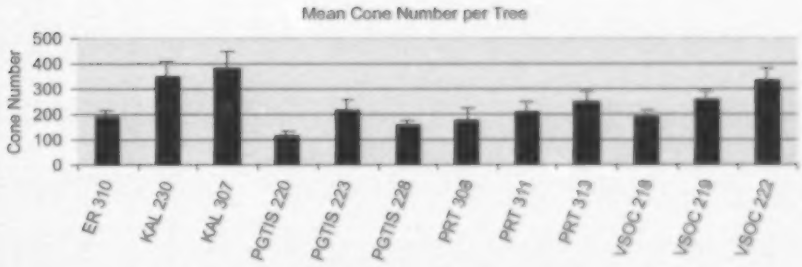


Figure 59. Mean cone numbers per tree (± standard errors) derived by estimating whole tree and a 30-cone sub sample for 12 lodgepole pine seed orchards (2006 orchard statistics).

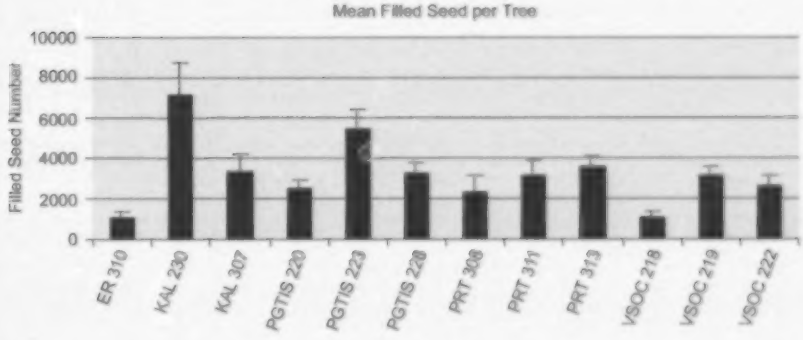


Figure 60. Mean filled seed production per tree (± standard error) for each of the 12 lodgepole pine seed orchards (2006 orchard statistics).

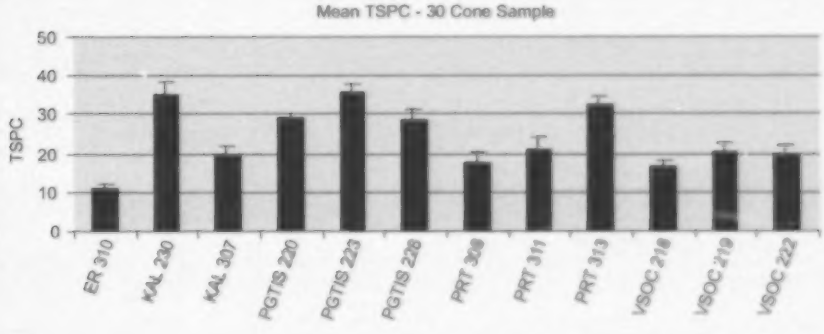


Figure 61. Mean total seed per cone (TSCP ± standard errors) for each of the 12 lodgepole pine seed orchards (2006 orchard statistics).

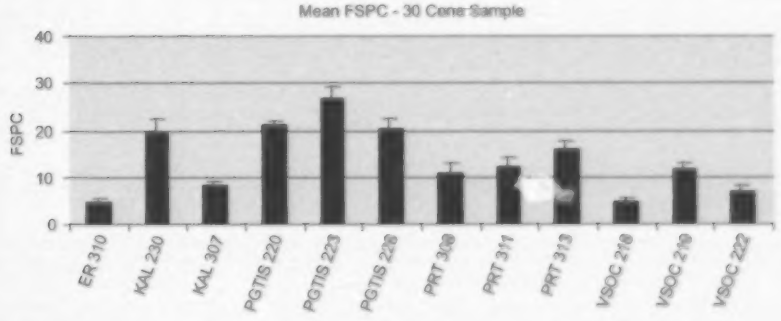


Figure 62. Mean filled seed per cone (FSPC ± standard errors) for each of the 12 lodgepole pine seed orchards (2006 orchard statistics).

Figure 63. Mean percent filled seed per cone (%FSPC +/-standard errors) for each of the 12 lodgepole pine seed orchards (2006 orchard statistics).

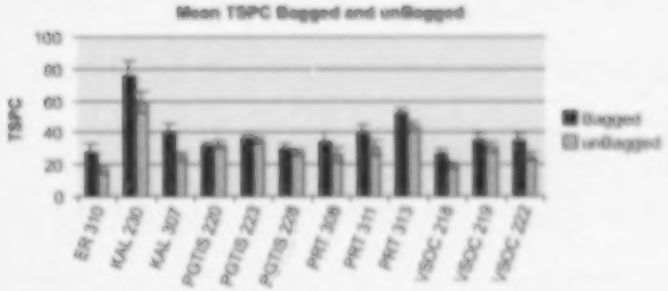


Figure 64. Mean total seed per cone (TSPC +/-standard errors) for insect protected cones (Bagged) and unprotected cones (unBagged) for each of the 12 lodgepole pine seed orchards (2006 orchard statistics).

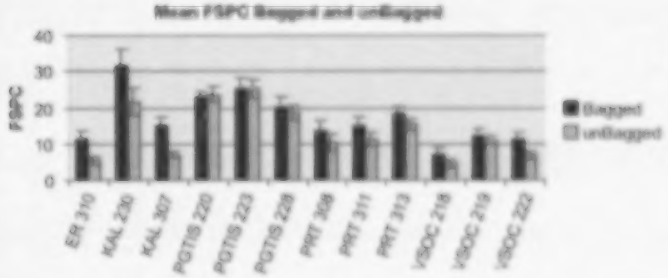


Figure 65. Mean filled seed per cone (FSPC +/-standard errors) for insect protected cones (Bagged) and unprotected cones (unBagged) from eachof the 12 lodgepole pine seed orchards (2006 orchard statistics).

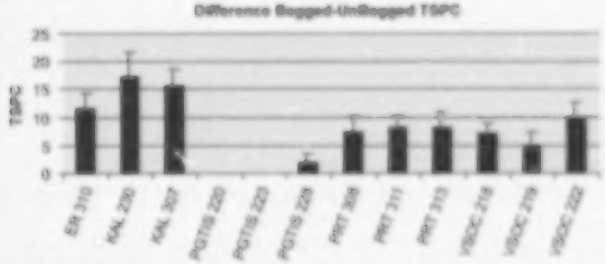


Figure 66. Mean difference (+/- standard errors) between TSPC from insect bagged cones and unbagged cones from each of the 12 lodgepole pine seed orchards (2006 orchard statistics).

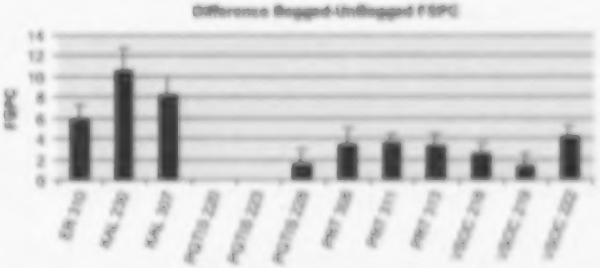


Figure 67. Mean difference (+/- standard errors) between FSPC from insect bagged cones and unbagged cones from each of the 12 lodgepole pine seed orchards (2006 orchard statistics).

effect) compared to the north Okanagan orchards. Kalamalka showed the biggest effect, with losses of over 10 and 8 PSPC for orchards 230 and 307 respectively. Eagle Rock showed losses in the order of 6 PSPC and PRT, and VSOC each had fewer than 4 PSPC losses.

Conclusions

The purpose of this orchard statistics project was to standardize the methods for estimating cone and seed production in all producing lodgepole pine seed orchards. The method of estimating cones per tree based on cone weight made comparisons between orchard sites and individual orchards more meaningful. This is also true for estimates of cone analyses (FSPC, TSPC, and seed weight), for general orchard production (30-cone sample), and insect effects.

Although the Prince George orchards produced the highest seed yields (FSPC), they also produced the fewest cones per tree. This made production from the north Okanagan orchards and Prince George orchards more equitable. Mean filled seed per tree ranged from about 1,100 to 7,200, with a grand mean of about 3,200. However, we are relying on the naturally inductive effect of the north Okanagan to produce more cones per tree. In general, the yields per cone from these orchards range from 10 to 15 fewer FSPC than we would expect. Certainly the losses due to insect predation are an important factor, but we cannot attribute all the losses to insect predation alone.

Because this is the first year of sampling, we cannot speculate on trends and the causes of losses in either cone numbers, FSPC, or TSPC. However, for most of the producing north Okanagan orchards, TSPC is critically lower than we would expect. Since insect bagging occurred around mid-April, we may infer that insect predation from mid-April also affected ovule development and resulted in fewer potential seed (TSPC).

The methodology used in this sampling project allowed direct comparisons of orchard yields from the 12 selected orchards. Next year, we may want to consider adding an estimate of crown size and tree age to further refine comparisons when orchard age and crown management practices are sufficiently different.

5.2.16 Female Differentiation Timing in Lodgepole Pine in Support of Operational Cone Induction

Patrick van Aalsburg, Gemma Eaechet, Sébastien Bonthoux, Samir Dendoncker, Lizhong Kong and Rebecca Wagner
Centre for Forest Biology
University of Victoria

Original objective

The objective of the project was to assess genotypic variation in female differentiation of lodgepole pine. The approach taken was a histological investigation of five clones. The originally submitted description and context follow.

Original project description

To increase production from PK orchards, we are proposing to study differentiation of female buds with a view to improving the timing of induction treatments. Current knowledge, according to all orchardists and breeders surveyed, is that lodgepole pine phenology in the Okanagan is difficult to gauge. In addition, the literature does not provide specific information in support of clear identification of female differentiation.

The problem with the published phenology of Owens (2006) is that it is so general as to be of little operational use. Because seasonality, genotypic variation, and phenological variation have not been established, from an operational standpoint every female cone induction treatment that is applied in the hope of increasing bud numbers and therefore cone numbers is applied without precise knowledge of when the optimal opportunities exist.

Abstract

Interior lodgepole pine is an important timber producing tree species in the interior of British Columbia. There is a high demand for improved seed that originates from seed orchards. A number of different methods are used to improve seed cone induction including controlled watering regimes, root pruning, and hormone induction. To time induction strategies effectively, a baseline knowledge of female strobili initiation and differentiation is needed. This study undertook histological analysis of long-shoot buds to identify female strobilus differentiation for five

genotypes of interior lodgepole pine. Genotypes were selected on the basis of established seed cone production and pollination receptivity. Biweekly collections were made from genotypes located at Kalamalka Research Station from July to October, 2000. Substantial inter-clone variation in the timing of female strobilus differentiation was found for the five clones analyzed. Female differentiation began in a period from late July to late August, depending on genotype. Lateral bud initiation and female bud initiation occur during the same period. In genotypes that showed male cone differentiation, sectioning revealed male cone buds had formed prior to our period of sample collection. These results suggest that cone induction may vary from two to three weeks between genotypes. Female differentiation in 2000 was earlier than previously reported in the literature.

Introduction

Interior lodgepole pine, *Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm, is an important timber producing tree species of Canada (Schlesh 1999). Due to the devastation of many lodgepole pine forests in British Columbia by the mountain pine beetle (*Dendroctonus ponderosae*), seeds are in great demand to mitigate the devastation of this pest (Amos, 2000). Two options are possible to increase seed production: increase seed yield per cone or increase cone yield. Seed yield per cone is generally optimized by adequate pollination and reduction of seed losses. To increase cone yields, conifer seed orchards have historically utilized many different cone induction strategies such as root pruning, stem girdling, crown pruning, and application of fertilizers and plant growth regulators (PGRs) (Beckwith Shainsbury and Webber 1995). Although many of these practices have proven practical, interpretation of the responses can be unclear. In particular, questions about the timing of applications still abound. This is due to a specific lack of precise knowledge of phenological variability of individual genotypes. Without this knowledge, accuracy in method application could not be achieved.

The legacy of a few generations of conifer morphologists has been a literature that describes various types of bud phenologies. Because the overall goal of such publications was to provide general outlines of bud formation, they were useful starting points for operational managers interested in studying bud development in their orchards. Operational improvements in induction treatments could be realized only if genotype-specific phenologies could be devised. These require close monitoring and an investment in studies of anatomy and morphology.

Interior lodgepole pine has a reproductive cycle of three years. It has compound buds, in which both female and male strobili, short-shoots, and lateral-shoots are preformed and protected under scales. Typified scales. In years of vigorous growth, interior lodgepole pine can display polycyclic growth (Greenwood 1986; O'Reilly 1986). Buds that differentiate in the first year include male, female, short-shoot, and lateral-shoot buds. Each one is separately initiated in the axils of cataphylls along the axis of the long-shoot bud. Generally, males are located at the bottom or proximal portion of the axis and females and lateral-shoot buds are located at the top or distal portion of the axis. Development of these buds continues until winter dormancy. In the second year, development continues. With bud mature and anthesis (pollen release) occurs. Female cones are receptive, but ovule development takes another year. Germinated pollen must wait in the micellus until the female reproductive tissue matures. During the third year of development, fertilization finally takes place, followed by embryogenesis and seed maturation (Owens 1995).

Understanding the timing of female strobilus differentiation is an important factor in ensuring that the full potential of cone induction activities is realized. In this study, we performed histological analysis of long-shoot buds in the first year of development from five clones of interior lodgepole pine.

Materials and methods

Plant material. Long-shoot buds of interior lodgepole pine (*Pinus contorta* var. *latifolia*) were collected from the Kalamalka Research Station near Vernon, BC. Ten buds were selected from a single ramet from each of five different clones (508, 1528, 1560, 1535, and 1539). Trees were selected which were in from the periphery of the orchard by at least five rows this was done to avoid edge effects. Collections were obtained from all areas of the crowns of the trees. Serial collections were carried out at approximately two week intervals from the beginning of July to the middle of October.

Fixation. The long-shoot buds were cut transversely and radially using a scalpel to allow a rough separation of male and female axillary buds. This also allowed superior infiltration of fixative and subsequent solutions. The fixative was composed of 2.5% glutaraldehyde in 0.05 M Sorensen's phosphate buffer (pH 7.2). Air bubbles were removed under vacuum at room temperature. Vials were stored in 4°C until further processing.

Dehydration Long-dried fruit samples were preprocessed for the organic dehydration series by a series of four washes in a solution of 0.05 M Sorensen's phosphate buffer (pH 7.2) at room temperature. After either the second or third wash, the fruit were dissected using tweezers and fine scissors.

Plant material was dehydrated by organic exposure to an increased concentration of ethanol in water (30%, 50%, 70%, 95%, 100%). Distilled de-ionised water (MilliQ) and anhydrous ethanol were used. Each step of the series was left for a period of 1 h, with the exception of the final step, which was left for 1.5 h.

Pre-infiltration Pre-infiltration was carried out according to the Technovit 7100 instructions. Pre-infiltration solution was made using a 1:1 ratio of Technovit base to 100% ethanol. Dehydrated fruit were immersed in approximately 5 times their volume and left at room temperature overnight.

Infiltration Infiltration solution was made up according to the Technovit 7100 instructions. One gram of Hardener I was mixed into 100 mL Technovit base. Fruit were immersed in at least five times their volume of infiltration solution. The solution was changed twice over the period of infiltration: once to replace the pre-infiltration solution and again on the third day of infiltration. After the last infiltration solution change, the vials were stored in refrigeration (4°C) until required.

Embedding Embedding solution was made up according to the Technovit 7100 instructions. Using a ratio of 1 mL Hardener II to 15 mL infiltration solution, the embedding solution was placed in embedding wells (3 cm diameter) using a Pasteur pipette. Fruit specimens were placed in the wells and covered with plastic film to allow the solution to polymerise. This step took place at room temperature.

Sectioning and staining Sections (5 µm) were obtained using a Leica 9003049 sledge microtome equipped with a tungsten carbide knife. Each section was manually flattened in distilled water on clear glass slides (Technologie Chevrot), then stained with one of the following stains: 0.1%toluidine blue (5 min) with sodium hypochlorite pre-treatment, 0.1% safranin (5 – 10 min) [illegible] with Ansul 5 post-treatment (Cremaster et al. 1999). Slides were dried at 50°C on a dish warmer, then mounted in Permount (Fisher Scientific) with clear glass cover slips (VWR Australia).

Sectioning strategy and avoidance of bias To prevent any bias occurring in the sectioning strategy, information concerning the properties of the original slices was withheld from the investigators until the end. In addition, the personnel who were trained to do the sectioning used an initial practice set of 6 slices samples, the results of which are not included. In this way, sample processing, filtration, dehydration, infiltration, and embedding) was optimised and staff gained experience in appropriate sectional without loss of critical samples. The total number of samples sectioned was 439 (see Table 1A). This represents the labour of two individuals processing and sectioning from September to mid-December. Most samples were sectioned from the 19 July to 15 August, 2000 collections because this period gave 4 to 6x the mean ovules[illegible]

Results

Female ovules appeared as large swollen buds with an apex resembling that of a half-moon. They were most easily distinguishable in their later stages of development (Figure 1B and subsequent). Most gymnosperm ovules[illegible] during the gametophyte stages of the hermaphrodite apex. Scales covering the developing ovules originated at the base of the bud.

The timing of female ovule[illegible] differentiation varied between the different trees (Table 1A). Female differentiation was easiest to verify in genotypes that were the high-production cone producers (Table 2A). The fruit example is 1260, in which only a few samples needed to be sectioned to find female buds. Juggle because female buds were abundantly available. In other samples, particularly low-producing trees (1324, 1330), it was more difficult to establish female differentiation, in spite of substantial sample sectioning effort (Table 1A).

Over the course of the summer, long-dried fruit continued to expand, with the various cones differentiating along their axes. There were visual differences in long-dried fruit elongation over the course of the growing season (Figure 1A). The cone with the greatest elongation (1324 and 1330) appeared to have the most delayed female development. The diverse was found with trees that had the least elongation (1324 and 1330). One tree — 1330 — had slow elongation initially but increased its rate of elongation, eventually reaching the consistently most elongated shoots. 1260 had early female development, which may be linked to the slower initial elongation.

These shoots with the longest long-dried fruit were from trees that historically had the least number of cones per tree (Table 2A). Assuming the long-dried fruit length is consistent from year to year and that the cone production

Table 4 Number of people convicted of drug offences and sentenced to immediate custody, 2000 to 2010

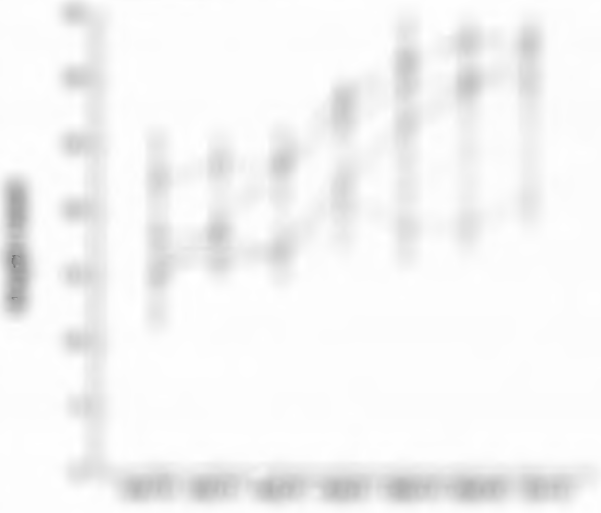
Table 5 Collection

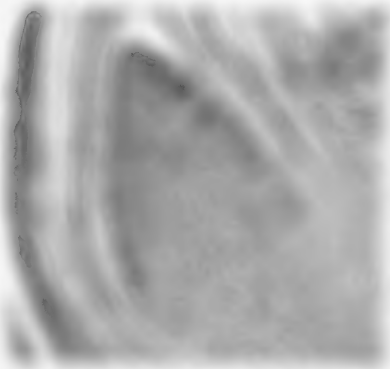
Table 6 Developing climate-related issues in the first three years of the Metropolitan Police's Violent Crime Reduction Unit

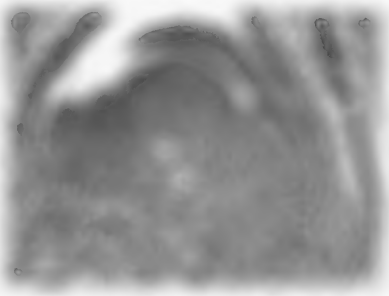
Table 7 Police recognition and detection of the first three years of the Violent Crime Reduction Unit

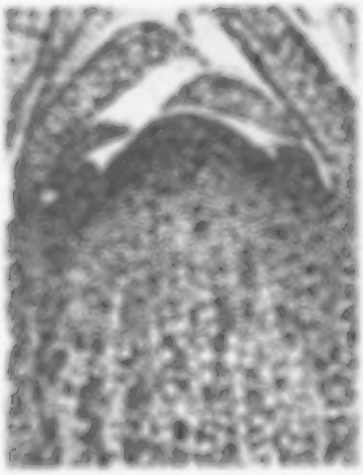
Table 8 Collection

Table 9 Table showing the distribution of Violent Crime Reduction Unit's first three years of the Violent Crime Reduction Unit's

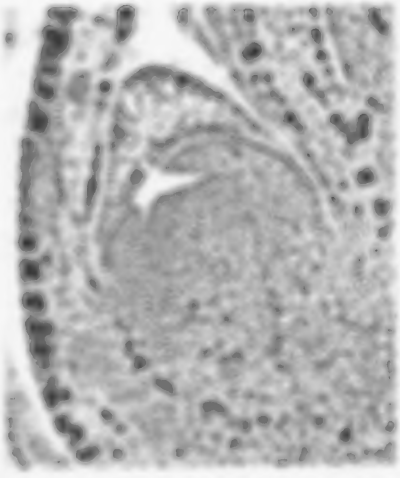




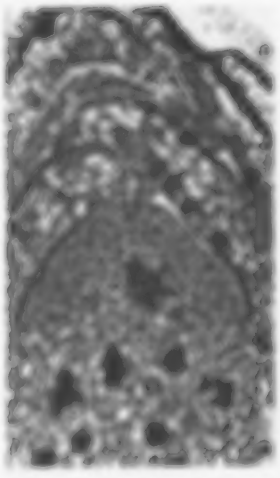


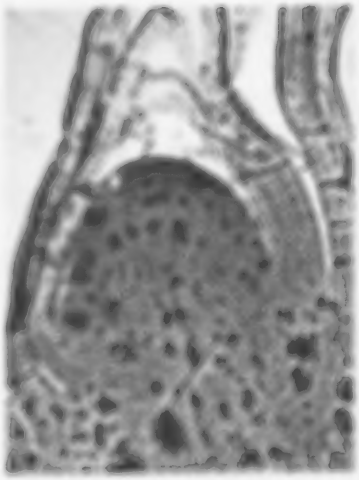


Long shoot bud meristem
August 31, 2006



Female buds
July 18, 2006





Female bud
August 16, 2006

5.2.17 Development of Yellow-Cedar Stock Plant Nutrition Guidelines to Enhance Operational Rooting of Elite Clones (SPU 1114)

Robert van den Driessche

Yellow-cedar reforestation in BC is almost entirely through clonal forestry using rooted cuttings. For example, the Ministry of Forests and Range Cowichan Lake Research Station grows stock plants chosen from selected yellow-cedar. These yellow-cedar plants have been selected because they have shown superior growth in the forest and also good ability to root from cuttings. The stock plants are grown outdoors, either in pots or field-planted, and are kept small by pruning because pruning, or "hedging," tends to slow the aging process. Slowing aging and maintaining juvenility is important for producing cuttings that grow like seedlings. That is, they root easily and have vigorous shoot growth. Research studies at CLRS have shown that serial propagation by using a proportion of each generation of rooted cuttings as hedges for the next generation conserves juvenility for about 15 years.

Recent operational experience indicates the potential benefit of growing stock plants in greenhouses for increasing the rooting of cuttings. This benefit may, in part, be attributed to a more optimal nutrient status for rooting ability among stock plants. Little is known about the effect of yellow-cedar stock plant nutrition on the rooting ability of cuttings, although nutrition is relatively easy to control and stock plant nutrition has been shown to influence the performance of cuttings in plants.

In particular, the balance between concentrations of total non-structural carbohydrates and nitrogen has been thought important for rooting, although the relationship of cutting performance to several nutrients has been reported. Additionally, production by the WFP Saanich nursery of yellow-cedar cuttings that rooted and grew vigorously was attributed to adding fertilizer to the stock plants during the fall. Consequently, we decided to study the importance of nitrogen and phosphorus, and the time of their application, to potted stock plants of different clones and ages at the CLRS. The objective is to relate different levels of nutrient status in stock plants, achieved with the fertilizer treatments, to subsequent rooting and growth vigour of cuttings. It should then be possible to recommend levels of stock plant nutrient status for the successful production of cuttings. So far, a small-scale experiment has produced cuttings that have been struck this winter, and samples of these cuttings are undergoing chemical analysis. Also plant material has been potted and prepared for a larger experiment that will be conducted during 2007 and 2008.

5.2.18 Fertility Variation in a Douglas-fir Seed Orchard as Determined by DNA Fingerprinting: an Update

Ben Lai, Annette Van Niejenhuis, and Yousry A. El-Kassaby

Because seed orchards represent the main sources of genetically improved seed for most artificially regenerated forests, they play an important interface role between tree breeding and silvicultural activities. The production of seed crops with high genetic quality (gain and diversity) in all BC orchards is critical to the success of tree improvement programs and to meeting the genetic quality required under the Chief Forester's Standards for Seed (2005).

This project is part of a larger initiative started by the BC Ministry of Forests and Range, the forest industry, and academia aimed at obtaining accurate estimates of the genetic quality of seedlots. Genetic quality is defined as the level of genetic gain combined with the degree of genetic diversity. Orchard managers routinely assess these estimates, and estimates such as genetic worth (GW) and effective population size (N_e) are an integral part of the evaluation of seed-orchard crops.

DNA fingerprinting technology coupled with methods of pedigree reconstruction will be used to obtain accurate estimates of the genetic contribution to a specific seedlot of each parent in Western Forest Products' Douglas-fir seed orchard. These estimates will be compared with survey assessment methods that are based on visual inspection of trees' reproductive output. Additionally, the use of DNA technology will permit the estimation of pollen contamination from outside sources and the effectiveness of orchard management practices such as supplemental mass pollination (SMP) and over-head cooling (bloom delay).

During this first year, the seed orchard parental population (53 clones) and the SMP parents were fingerprinted. Additionally, DNA samples from 1,300 pairs of megagametopytes (haploid) and their corresponding embryos (diploid) were extracted from a random sample of the orchard's bulk seed, and their fingerprinting is expected to be completed during the second year.

Two data analyses approaches will be attempted, one utilizing a computer program that was developed specifically to handle bulk seed, and the second utilizing a program developed by Slavov et al., 2005. These analyses are expected to allow the determination of every clone's gametic contribution.

The results will aid in the accurate estimation of the genetic worth and diversity of the orchard's seedlot by relating the DNA results to the visual assessments of reproductive output. The resulting correlations will be used to assess the various survey methods and to calibrate survey methodologies as appropriate.

5.3 Mountain Pine Beetle Incremental Projects

5.3.1 Pollen Management in Lodgepole Pine Orchards: Project 405724E

George Nicholson

Young lodgepole pine orchards produce very little pollen in the early years. This project was designed to collect pollen from the older Thompson Okanagan 310 orchard and reapply it to the young ramets in orchard 339.
The pollen was vacuum collected, and this allowed us to reapply the pollen in the same season. We collected a total of 10 litres of pollen and applied three litres to the orchard. The balance of the pollen was put into freezer storage for future use.

5.3.2 Effective Crown Pruning in Lodgepole Pine: Project 4057E25

George Nicholson

This is a multi-year project designed to stimulate cone production in the top third of the crown. Both top and upper lateral branches were pruned.

We used mechanical shears to prune in most cases or a small chain saw if stem diameter was too large. The level of pruning in the orchards may reduce the cone production in the year following, but this effect will not be long lasting.

During the fall of 2006, a total of 580 ramets were top and lateral-branch pruned in the mature Thompson Okanagan 310 orchard. We will top prune a further 1,000 ramets in orchard 339 in 2007 and 1,500 ramets in 2008. The top pruning in the younger orchard will help control the ramet height and increase the number of potential cone sites.

5.3.3 Upgrading of Lodgepole Pine Superior Provenance Seed: Project 4057E26

Dave Kolotelo

This project attempted to upgrade the germination of a lodgepole pine superior provenance (Rocky Mountain Trench) seed lot (2612 – collected 1972). In the past this seed lot was approved for disposal for reasons associated with poor germination (64 percent). It is an atypical seed lot because its dry (D1) test has consistently performed better than a stratified (G20) test. An inventory of 96 kg of seed (equivalent to approximately 5.5 million seedlings) exists, and we attempted to upgrade the seed lot because of its size and its expanded range (BSH; EK; MRB; SA; TOD and WK seed planning zones).

Seed-lot evaluations indicated the presence of mechanical seed-coat damage, seed-coat chitting, and heat damage. We used liquid separation of a partially imbibed product and pre-vac to try and remove this fraction (referred to as poor). The table following provides an overview of the processing results. Germination of the upgraded fraction increased only slightly (67 to 70 percent),

but there was a substantial decrease in potential seedlings. We found no fungal contamination (*Fusarium* spp.) or infection (*Caloscypha fulgens*) in any of the seed fractions. The liquid separation was not very efficient because the poor fraction still germinated at 43 percent, although with the attempt to remove the chitted seed, we expected that some germination would occur in the poor fraction. We don't consider this effort a success, and future upgrading efforts with seed lots of similar seed characteristics and quality are likely to produce similar results.

Portion	Volume	Pot. Trees	D1 GC	W1 GC	G20 GC
CONTROL	**96.0 Kg**	**6.36 M**	**67%**	**50%**	**39%**
Upgraded	80.3 Kg	5.48 M	70%	42%	40%
Poor	15.5 Kg	0.62 M	43%	29%	18%

Table 28.

5.3.4 Engineering Consultation for Kiln and/or Controller Upgrades: Project 4057E27

Dave Kolotelo

The funds for to this project were allocated to two separate kiln projects:

a) training and upgrades to our ARGUS Control System

b) engineering evaluation of our kiln

With regard to our ARGUS system, we had a meeting with one of the manufacturer's technicians/programmers to better understand the operational complexities of our kiln programming. We also invested in an upgrade to our ARGUS software, including some application engineering time.

To obtain an engineering evaluation of our kiln, we extended an invitation to quote, and the successful company was Custom Air Conditioning Ltd. The primary issues addressed were the inability to maintain humidity levels and the inability to keep temperatures within the kiln at the desired set points. A thorough investigation of the mechanical system determined that:

a) all components were operating properly

b) the temperature variation was within acceptable parameters (± 2°F)

c) the burner completely shuts down after reaching set point

d) high temperature overshoot is attempted to be overcome by venting

e) humidity set points are not achievable over the duration of the kiln

f) the burner system is antiquated and not energy efficient by today's standards

The engineering recommendation is that even with significant modifications to our existing kiln, we will not be able to maintain both temperature and humidity set points. At 21 years of age and without any modifications, our existing kiln design is perhaps beyond its period of useful life. The recommendation is to remove the existing burner configuration and replace it with a packaged dehumidifier system (heat pump) with the ability to add steam to the kiln. This is a very energy efficient system and will reduce natural gas use.

The total cost of this improvement is in the range of $75,000 to $100,000, and equipment delivery and installation would require approximately 17-22 weeks. No other minor changes were recommended, and that is why the project spent only about 60 percent of the allotted funding.

6.0 Extension and Communications

6.1 ETAC Extension and Communications

Diane Douglas

Field Tours and Workshops

- Prince George area field tour – Anna Monetta with the Northern Silviculture Committee (NSC) approached ETAC regarding a Forest Genetics field tour following the June NSC on June 22, 2006. The tour was a resounding success, with registration logistics handled by Rob Bryce of UNBC and excellent presentations by Michael Carlson, Barry Jaquish, and Richard Reich. David Reid and Rita Wagner hosted the tour of PGTIS.

New picnic tables, planters, and some painting made the site look great despite all the destruction by MPB.

There were young foresters, lots of interest, and lots of questions. The tour ran from 8:00 to 3:30. Attendees numbered approximately 45 – 50.

- Interior Pollen Management Workshop – Dr. Joe Webber conducted the workshop on November 22 and 23 at VSOC in Vernon with 27 people in attendance.

Publications

- "Tree Improvement in BC" posters are now available in three formats: 24" x 36" poster, 11" and 18" poster, and single-page handouts. They are also available on the Forest Genetics website. http://www.fgcouncil.bc.ca/Tree-Improv-8x11.pdf
- The first draft of the "Spruce Manual for Seed Orchardists" was prepared by Jodie Krakowski and John King.
- "Conifer Reproductive Cycle" diagrams and illustrations were colorized and will be made available via the web.
- "Extension Note 9, Increasing Quality Seed Production in Western Redcedar Orchards: A Synthesis of a multi-year folia applied gibberellin A3 study" by John Russell and Oldrich Hak was completed. Copies have been printed for distribution, and it is also available at on the web.
- "TIC*talk* – Volume 7" was available in December 2006. Initially, the newsletter was web based only. However, 150 copies have also been printed for distribution at field days and workshops. http://www.fgcouncil.bc.ca/Tictalk_Dec2006-Final-Web.pdf
- The publication "The Reproductive Biology of Western Larch", in preparation by the the Inland Empire Tree Improvement Community will be published and printed by ETAC.

Figure 75. Prince George area forest genetics field tour.

7.0 Seed Orchard Pest Management

Robb Bennett

The Seed Orchard Pest Management Subprogram supports research, extension activities, and pest management operations to increase orchard yields of high quality seed. A Ministry of Forests and Range (MFR) Research Branch scientist (Dr. Ward Strong) leads the research component. MFR Tree Improvement Branch personnel (Jim Corrigan and Dr. Robb Bennett) deliver extension services. Seed orchard personnel handle operational activities. The Pest Management Technical Advisory Committee (PMTAC) guides investments and activities. The PMTAC is comprised of members from MFR Research and Tree Improvement Branches, the Canadian Forest Service, private seed orchards, universities, and the Forest Genetics Council.

Research plans and budgets are established through an annual process of proposal development and discussions by the PMTAC. Priority issues not currently being addressed through this process are subject to a public call for proposals. Currently (2006/07) the PMTAC is administering projects on *Leptoglossus* seed bugs, *Dioryctria* cone worms, *Fusarium* fungi, adelgids, mountain pine beetle, systemic pesticides, a cone crop monitoring system, and a cone and seed insect field guide. Projects showing significant progress in 2006/07 fiscal year are summarized below.

Project	Species primarily impacted	Progress
Conifer seed bug (*Leptoglossus occidentalis*): damage control methods	All Pinaceae	Demonstrated that *Leptoglossus* seedbugs find hosts through infrared detection and respond to vibrational stimuli when on hosts. Based on this a novel trap is being developed
Fir coneworms (*Dioryctria* spp.): Identification of an effective sex pheromone lure and the demonstration of its efficacy in seed orchards	Fdi, Fdc, Sx	Pheromone characterization completed. Refinements to production methodology underway. Adult monitoring conducted throughout field season to determine flight period on coast and in interior
Fusarium fungi: reducing infections in orchard seed -determining infection mechanisms	All species	Work completed. Summary report encapsulating results of several related projects has been drafted for publication.
Conifer adelgids (*Adelges* and *Pineus* spp.): species composition, biology, and density/damage relationships	Sx, Lw, Fdi, Fdc, Pw	Initial species composition and population parameters analysis completed
Systemic insecticides: tests for cone and seed insect control	All species	The second year of pesticide trials at coastal and interior sites produced inconclusive results. Based on this, the trials were restructured to look at new injectable formulations

Table 29.

Appendix 1 FGC Seed Planning Units

SPU Unit (OTIP)	Seed Planning Unit (SPU)	Species	Seed Planning Zone (SPZ)	Elevation Band (metres)	
		Common name		Min	Max
1	FDC M LOW	Douglas-fir	M	1	700
2	CW M LOW SOUTH	Western redcedar	M	1	600
3	HW M LOW SOUTH	Western hemlock	M	1	600
4	SX NE MID	Interior spruce	NE	800	1500
5	SX NE HIGH	Interior spruce	NE	1500	1900
6	SS M LOW SOUTH	Sitka spruce	M	1	500
7	PLI NE LOW	Lodgepole pine	NE	700	1400
8	PW M LOW	Western white pine	M	1	1000
new	PW M HIGH	Western white pine	M	1000	1400
9	BA M LOW	Amabilis fir	M	1	700
10	PLI TO LOW	Lodgepole pine	TO	700	1100
new	PLI TO MID	Lodgepole pine	TO	1100	1400
11	YC M ALL SOUTH	Yellow Cedar	M	1	1100
12	PLI PG LOW	Lodgepole pine	PG	700	1200
13	LW NE LOW	Western larch	NE	700	1400
14	SX PG LOW	Interior spruce	PG	600	1200
15	PW KQ ALL	Western white pine	KQ	500	1200
16	PLI TO HIGH	Lodgepole pine	TO	1400	1600
17	PLI BV LOW	Lodgepole pine	BV	700	1200
18	PLI CP LOW	Lodgepole pine	CP	700	1100
19	FDC SM LOW	Douglas-fir	SM	200	1000
20	PLI NE HIGH	Lodgepole pine	NE	1400	2000
21	FDI NE LOW	Douglas-fir	NE	400	1000
22	FDI NE HIGH	Douglas-fir	NE	1000	1600
23	SX SM ALL	Interior sitka hybrid	SM	1	1800
24	HW M HIGH SOUTH	Western hemlock	M	600	1100
25	SX EK ALL	Interior spruce	EK	750	1700
26	PLI PG HIGH	Lodgepole pine	PG	1200	2000
27	CW SM ALL	Western redcedar	SM	200	1000
28	SX TO HIGH	Interior spruce	TO	1300	1900
29	PLI EK HIGH	Lodgepole pine	EK	1500	2000
30	SX TO LOW	Interior spruce	TO	700	1300
31	FDC M HIGH	Douglas-fir	M	700	1200
32	PLI EK LOW	Lodgepole pine	EK	800	1500
33	CW M HIGH	Western redcedar	M	600	2000
34	LW EK ALL	Western larch	EK	800	1500
35	SX BV LOW	Interior spruce	BV	500	1200
36	BG M LOW	Grand fir	M	1	700
37	FDI QL LOW	Douglas-fir	QL	700	1200
38	HW M LOW NORTH	Western hemlock	M	1	600
39	FDI EK ALL	Douglas-fir	EK	700	1400
40	SX PR LOW	Interior spruce	PR	450	650
new	SX PR MID	Interior spruce	PR	650	1200
41	FDI PG LOW	Douglas-fir	PG	700	1000
42	SX PG HIGH	Interior spruce	PG	1200	1550
43	FDI CT LOW	Douglas-fir	CT	600	1200

Source: Ministry of Forests, Tree Improvement Branch (SPU, Version 3.0: April, 2005)

Appendix 2 Tree Species

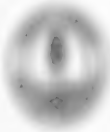
CONIFERS	LATIN NAME	ABBREVIATIONS
western redcedar	*Thuja plicata*	Cw
yellow cedar	*Chamaecyparis nootkatensis*	Yc
Douglas-fir	*Pseudotsuga menziesii*	Fdc
Interior Douglas-fir	*Pseudotsuga menziesii* var. *glauca*	Fdi
amabilis fir	*Abies amabilis*	Ba
grand fir	*Abies grandis*	Bg
noble fir	*Abies procera*	Bp
subalpine fir	*Abies lasiocarpa*	Bl
mountain hemlock	*Tsuga mertensiana*	Hm
western hemlock	*Tsuga heterophylla*	Hw
Rocky Mtn. juniper	*Juniperus scopulorum*	Jr
alpine (subalpine) larch	*Larix lyallii*	La
western larch	*Larix occidentalis*	Lw
limber pine	*Pinus flexilis*	Pf
lodgepole pine	*Pinus contorta*	Pl
lodgepole pine	*Pinus contorta* var. *latifolia*	Pli
ponderosa pine	*Pinus ponderosa*	Py
shore pine	*Pinus contorta* var. *contorta*	Plc
western white pine	*Pinus monticola*	Pw
whitebark pine	*Pinus albicaulis*	Pa
Engelmann spruce	*Picea engelmannii*	Se
Sitka spruce	*Picea sitchensis*	Ss
white spruce	*Picea glauca*	Sw
spruce hybrid (Interior spruce/x)	*Picea cross* (Se and Sw mixtures)	Sx
Sitka x unknown hybrid	*Picea sitchensis* x	Sxs
western (Pacific) yew	*Taxus brevifolia*	Tw
HARDWOODS		
red alder	*Alnus rubra*	Dr
black cottonwood	*Populus b. ssp. trichocarpa*	Act
hybrid poplars	*Populus* spp.	At
trembling aspen	*Populus tremuloides*	At
paper birch	*Betula papyrifera*	Ep
Garry oak	*Quercus garryana*	Qg

Appendix 3 Discussions by Tree Species

CONIFERS	ABBREVIATION	PAGE LOCATIONS
subalpine fir	Bl	11
western redcedar	Cw	11, 20, 23, 25, 59
coastal Douglas-fir	Fdc	8-9, 20, 23, 36, 71
interior Douglas-fir	Fdi	13-14, 23, 49
western hemlock	Hw	10, 23, 24, 25, 49-52
western larch	Lw	10
lodgepole pine	Pl	5, 17, 28, 31, 32, 36, 42-44, 47-48, 52-53, 59-63, 63-69, 72
ponderosa pine	Py	17
western white pine	Pw	5, 12, 17, 23, 24
sitka spruce	Ss	10, 22, 49-52
spruce hybrid (interior spruce)	Sx	25, 31, 32, 44, 54-59
yellow cedar	Yc	11, 22, 39, 45, 46, 71
BROADLEAVES		
black cottonwood	Act	13
red alder	Dr	13
paper birch	Ep	17
bigleaf maple	Mb	13
PEST		
Adelgids		71
Dioryctria spp.		71
Fusarium		56, 71
Lymantria monacha		71
Pythium		59

Appendix 4 Author Contact List

CONTRIBUTOR	AFFILIATION	TELEPHONE NUMBER
Aitken, Sally	UBC	604-822-4549
Ashley, Valerie	MPR	250-245-4772
Bailey, Brian	MPR	250-245-4888
Brunner, Keith	MPR	250-832-6700
Briggs, Vicky	MPR	250-245-4767
Bird, Keith	MPR	250-746-0811
Brown, Paul	UBC	604-885-5868
Carlson, Michael	MPR	250-245-4767
Carson, Don	MPR	250-746-0811
Cartwright, Charlie	MPR	250-387-1477
Cox, Keith	MPR	250-828-4828
Crombie, Tim	TimberWest	250-832-1211
Douglas, Diane	MPR	250-356-4723
Dugas, Dale	MPR	250-387-2170
El-Kassaby, Yousry	UBC	604-822-1493
Hamby, John	Weyco Global	250-949-8926
Ferguson, Craig	MPR	250-746-0811
Gaudet, Dan	TREE	250-832-8826
Gemmo, Gary	MPR	250-746-1074
Graham, Allen	PRT	250-748-4714
Griffin, Mark	MPR	250-746-0811
Hak, Oldrich	Consultant	250-727-4389
Hamman, Rick	ESRD	250-832-0272
Higson, Lisa	MPR	250-387-5843
Hodge, Bonnie	MPR	250-963-8630
Hunt, Rick	CIS	250-746-7356
Ingram, Barry	MPR	250-245-4766
King, John	MPR	250-387-6478
Kolotelo, Dave	MPR	604-541-1963
Lai, Bee	UBC	604-822-1493
Lehr, Carolyn	MPR	250-832-5858
McKinley, Leslie	MPR	250-356-4208
Murphy, John	MPR	250-245-4767
Nicholson, George	Tolko	250-546-2288
Pigg, John	MPR	250-746-0811
O'Neill, Greg	MFR	250-245-4775
Phillips, Gisele	MPR	250-245-4756
Rogers, Greg	Tolko	250-546-2288
Rosenfeld, Dave	MPR	250-387-1458
Rudi, David	MPR	250-832-5858
Russell, John	MPR	250-746-0811
Strubi, Michael	MPR	250-356-4209
Thomas, Keith	MPR	25-356-1127
Van Steenbrugge, Annette	WFP	250-832-4923



[illegible]	[illegible]	[illegible]
Yue-Jen Chiayulu, Robert	[illegible]	[illegible]
Yun-Wenkao, Patrick	[illegible]	[illegible]
Wiggins, Ron	[illegible]	[illegible]
Wiggins, Tim	[illegible]	[illegible]
Webb, Chris	[illegible]	[illegible]
Watkins, Jon	[illegible]	[illegible]
Woods, Jack	[illegible]	[illegible]
Xu, Chang-Yu	[illegible]	[illegible]